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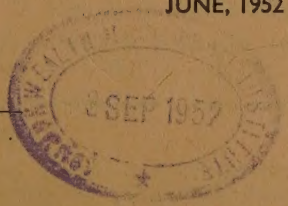

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NOTICES

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VOLUME 34

A. AGRICULTURAL RESEARCH SECTION

NEW ZEALAND
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CYANOGENESIS IN WHITE CLOVER (*Trifolium Repens* L.)

VI. EXPERIMENTS WITH HIGH-GLUCOSIDE AND GLUCOSIDE-FREE STRAINS

By L. CORKILL, Grasslands Division, Department of Scientific and Industrial Research, Palmerston North

(*Received for publication, 15 September 1950*)

Summary

1. In a white clover progeny segregating for the glucoside lotaustralin and for the enzyme linamarase, there was no significant difference in green weights between plants with and without the glucoside, or plants with and without the enzyme.

2. A non-cyanogenetic strain of white clover has been produced which is free from the glucoside lotaustralin but contains the enzyme linamarase.

3. This clover is equal in production to the strongly cyanogenetic New Zealand certified pedigree strain and superior to certain other New Zealand strains.

4. The use of the cyanophoric character in the certification of white clover is described and the limitations of the picric acid test in detecting contamination in high-glucoside clover indicated. The greater sensitivity of the test in detecting contamination in the glucoside-free strain is shown.

5. The cyanophoric properties of New Zealand strains of white clover are discussed in relation to their possible origin.

6. An experimental strain of a very strongly cyanogenetic white clover has been produced. Analyses on leaves have shown it to contain up to 0.035 per cent HCN.

7. Observations on the palatability to sheep of this and other strains are described, and the possible effect on animal thrift discussed.

INTRODUCTION

The cyanogenetic glucosides of white clover have been isolated and identified by Melville and Doak[1] as consisting of 80 per cent lotaustralin and 20 per cent linamarin. The enzyme which hydrolyses these glucosides to produce free HCN has been identified by Coop[2] as linamarase.

Previously Doak[3] showed that the most productive and persistent strains of white clover in New Zealand were the highest in cyanogenetic glucoside. Foy and Hyde[4], working with seed samples of a wide range of white clover strains, found good correlation between glucoside content as measured by the picrate paper test on seedlings, and agronomic type as determined by plot trials. Subsequent to these findings the New Zealand Department of Agriculture used the picrate test as a means of clover strain identification in the seed certification system.[5]

Concurrently with the above work strains of white clover were being bred for greater leaf production. In view of the correlation which had been shown between high glucoside content and high productivity in New Zealand strains of white clover it seemed possible that selection for greater production might induce a rise in glucoside content. To provide information on this point, investigations on the inheritance of the cyanophoric character were carried out. It was shown by Corkill[6] that individual plants of white clover could contain both enzyme and glucoside, enzyme only, glucoside only, or neither. The inheritance of cyanogenesis was found by Corkill[7] to be governed by the interaction of simple dominant genes for the enzyme and the glucoside. These genes were not linked. Differences in the quantity of the glucoside in different plants were probably due to the effect of modifying genes. Similar findings were reported by Atwood and Sullivan[8].

The investigations reported in this paper deal with further aspects of the relationship of cyanogenesis to the breeding and certification of agronomically superior strains of white clover.

EXPERIMENTAL METHOD AND RESULTS

Relationship of Glucoside and Enzyme to Plant Productivity.

To determine any difference in productivity between plants with and without glucoside, and between those with and without enzyme, green weights were obtained of 291 plants of a progeny segregating in a 3 : 1 ratio for glucoside and for enzyme. The progeny was obtained by sib-crossing plants from a cross between a vigorous large-leaved highly productive plant of a New Zealand line with a small-leaved low producing plant. This latter had originated from a cross between a vigorous plant of a New Zealand line and a non-vigorous plant from a Kentish wild-white clover line. As might be expected from a sib-cross of this origin there was wide variation in productivity between progeny plants.

Plants from seed sown in flats in June were planted in the field in October at two-foot intervals in six randomised blocks of 50 plants each. They were tested for the presence of enzyme and glucoside by the modified picrate test as described in a previous paper[6]. Three test tubes each containing a few young leaves (approximately $\frac{1}{4}$ g) from the one plant were used. To one tube was added one drop of a 0.5 per cent solution of lotaustralin and to another one drop of 0.5 per cent linamarase. From the reaction in these tests a plant could be classified as containing both enzyme and glucoside, enzyme only, glucoside only, or neither.

During the first year after planting, growth of the plants was controlled by periodic grazing with sheep. In November 1942, when the plants were growing vigorously, green weights were obtained by cutting the plants close to ground level. After this cutting, the plants were

grazed twice, and in the following May green weights were again obtained. Of the 291 plants weighed, 216 contained glucoside, and 75 were free from glucoside. There were also 216 with enzyme and 75 without enzyme.

The weights of herbage from both cuts were used to determine whether plants with glucoside differed significantly in green weight from those without glucoside. A similar comparison was made between the plants with and without enzyme.

An analysis of variance was made on the individual plant weights from both cuts. The data are summarized in Table I for the glucoside comparison, and in Table II for the enzyme comparison.

TABLE I. MEAN GREEN WEIGHTS OF HERBAGE (IN GRAMS) PER PLANT FROM TWO CUTTINGS OF PLANTS WITH AND WITHOUT GLUCOSIDE

Varieties	Blocks						Means
	1	2	3	4	5	6	
With Glucoside	683	614	570	625	562	603	608.1
Without Glucoside	689	582	510	614	541	465	571.9

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	F
Blocks	5	301,577	60,315	4.5 **
Varieties	1	36,587	36,587	2.72
Error	284	3,825,592	13,470	
TOTAL	290	4,163,756		

The percentage difference between the mean weights of the plants with and without glucoside is small, and is not significant at the 5 per cent level. There is likewise no significant difference between the weights of the plants with and without the enzyme.

TABLE II. MEAN GREEN WEIGHTS OF HERBAGE (IN GRAMS) PER PLANT FROM TWO CUTTINGS OF PLANTS WITH AND WITHOUT ENZYME

Varieties	Blocks						Means
	1	2	3	4	5	6	
With Enzyme	718	597	548	630	555	582	605.2
Without Enzyme	625	611	590	582	561	523	577.3

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	F
Blocks	5	66,288	133,258	4.81 **
Varieties	1	43,280	43,280	1.56
Error	284	7,874,011	27,725	
TOTAL	290	8,583,579		

From the data in Tables I and II it would appear that there should be no difficulty in breeding a strain of white clover free from glucoside and enzyme and as productive as the high-glucoside New Zealand certified strain. A strain free from glucoside, but containing enzyme, has in fact been produced at the Grasslands Division. In progenies from plants which had been used to breed the pedigree strain of high-glucoside white clover already in commerce there were some plants with the enzyme but no glucoside. A number of such individuals which produced vigorous progenies were selected from eight unrelated progenies and combined together to provide a small seed supply of a strain containing the enzyme but no glucoside.

This strain was used in the experiment described below.

The Productivity of the Glucoside-free Strain compared with Certain Other White Clover Strains.

Two trials were carried out at Palmerston North to compare the productivity of the glucoside-free strain with that of three other strains, namely, a high-glucoside pedigree strain, a high-glucoside certified strain of "natural" origin, and an uncertified New Zealand strain.

Trial A

In this trial the four strains were planted out as individual plants spaced at two-feet intervals in a randomised block layout. Of each strain there were 120 plants in four blocks each of 30 plants. They were planted in the field on 20 November 1947. On seven occasions between 29 January 1948 and 7 April 1949 the plants were cut close to ground level and the herbage weighed individually. The data from the seven cuts are summarized in Table III.

TABLE III. TOTAL GREEN WEIGHTS OF HERBAGE (IN GRAMS) AND MEAN YIELDS PER PLANT FOR SEVEN CUTTINGS OF FOUR STRAINS OF WHITE CLOVER

Strains	Blocks				Mean
	1	2	3	4	
Glucoside free	39,096	42,474	37,458	36,962	38,998
Pedigree	39,248	36,636	35,508	31,978	35,843
Certified "natural" strain	29,817	22,026	24,412	25,570	25,456
Uncertified	11,926	11,637	11,861	8,821	11,061

Strains	Cuttings							Plant means
	1	2	3	4	5	6	7	
Glucoside free	239.2	108.9	193.2	172.2	260.7	153.7	172.1	185.7
Pedigree	247.2	79.9	187.5	159.0	225.1	134.8	161.1	170.7
Certified "natural" strain	231.3	34.6	93.4	102.6	168.3	100.6	117.7	121.2
Uncertified	180.6	10.4	29.0	27.8	51.8	30.7	38.5	52.7

ANALYSIS OF VARIANCE

Source of variation	d.f.	s.s.	m.s.	F
Blocks	3	175,143	58,381	2.3
Strains	3	9,061,686	3,020,562	119.6 **
Error 1	9	227.267	25,252	
Cuttings	6	8,206,760	1,367,793	288.4 **
Variety x cutting	18	1,166,555	64,809	13.7 **
Error 2	72	341,514	4,743	
Between plants	3,248	16,876,887	5,196	
TOTAL	3,359	36,055,812		

The difference between plant means required for significance at the 5 per cent level is 17.5 g, and at the 1 per cent level, 25.2 g.

In total yield there is no significant difference between the glucoside-free and pedigree strains, but both are significantly higher in production at the 1 per cent level than the other two strains. The certified " natural " strain is significantly better than the uncertified strain at the 1 per cent level of significance.

When the yields from individual cuttings are considered, the relative productivity of the strains is as follows:—

The glucoside-free, pedigree, and certified "natural" strains are, in all cuttings, superior at the 1 per cent level to the uncertified strain.

The glucoside-free strain in all cuttings, and the pedigree strain in all but the first cutting, are more productive than the certified "natural" strain at the 1 per cent level.

The glucoside-free strain is significantly higher yielding than the pedigree strain in three cuttings, whilst there is no significant difference in the other four.

These four strains of white clover have also been compared on a dry-weight basis. For each of the seven cuts the dry weight of each plot was obtained by oven drying a composite sample of the thirty plants comprising that plot. The data from the dry weights showed a relationship between strains similar to that obtained from green weights of individual plants.

Trial B

The productivity of the four strains was also compared in a trial where they were sown broadcast on 24 September 1947 in duplicated 1/400 acre plots. Production was measured by mowing. The total production in lb dry matter per acre for 21 cuttings made between 30/1/48 and 20/1/50 is given in Table IV.

The difference between mean yields required for significance at the 5 per cent level is 1941 lb, and at the 1 per cent level, 3563 lb.

TABLE IV. TOTAL DRY WEIGHTS OF HERBAGE IN LB PER ACRE FOR 21 CUTTINGS OF 4 STRAINS OF WHITE CLOVER

Strains	Blocks		Mean
	1	2	
Glucoside free	22,479	22,470	22,475
Pedigree	21,819	21,603	21,711
Certified "Natural" Strain	19,503	20,254	19,879
Uncertified	13,758	15,446	14,602

ANALYSIS OF VARIANCE

Source of variation	d.f.	s.s.	m.s.	F
Blocks	1	612,717	612,717	1.6
Strains	3	75,517,890	25,172,630	67.6 **
Error	3	1,117,326	372,442	
TOTAL	7	77,247,933		

There is no significant difference between the glucoside-free and pedigree strains, but both are significantly better than the "natural" certified strain (the glucoside-free at the 5 per cent level and the pedigree at the 6 per cent level of significance). The three are significantly higher producing than the uncertified strain at the 1 per cent level.

In each trial very similar information is obtained on the relative productivity of the strains. The glucoside-free and pedigree strains are not significantly different; both are superior to the "natural" certified strain, but in Trial A the relative superiority is greater. All are significantly better than the uncertified strain at the 1 per cent level.

In these two trials the glucoside-free strain has proved to be equally as productive as the high-glucoside pedigree strain and more so than the certified "natural" strain which is also high in glucoside.

Palatability Trials with Glucoside-free and High-Glucoside Strains of White Clover

Observational trials have been made on the relative palatability to sheep of white clover strains very high in glucoside content and of those without glucoside. In addition to the glucoside-free strain already mentioned, a white clover strain much higher in glucoside than the New Zealand certified strain has been produced for experimental purposes. For breeding this high-glucoside strain, use was made of progenies used in breeding the certified strain of white clover. From these progenies plants were selected which gave an intense reaction under the picrate test, indicating a high percentage of glucoside. To determine the genotype of these plants for enzyme and glucoside they were test-crossed to plants recessive for these characters, and picrate tests, using linamarase and lotaustralin, were made on the progeny plants. These tests indicated not only the genotype, but also, from the intensity of the reactions, provided a good indication of the breeding potentialities of the parents for quantity of glucoside. Finally, nine plants were selected and combined to produce a seed supply of the experimental strain. These selected plants were all homozygous for glucoside and high in percentage glucoside. All contained enzyme and most were homozygous for it.

Chemical analyses made on leaves at three different periods showed the percentage of HCN on a green weight basis in this experimental strain and the New Zealand certified pedigree strain to be 0.0242, 0.0309, 0.0351 for the experimental strain, and 0.0163, 0.0201, 0.0193 for the pedigree strain. The experimental strain is thus 49 to 82 per cent higher in glucoside than the certified strain which itself is considered high in HCN.

For palatability trials the three strains (glucoside-free, high-glucoside and certified) were sown in four replications in contiguous plots measuring 45 x 15 links. In two replications the clover was sown alone to produce a pure stand, and in the other two in a mixture with perennial ryegrass.

Over a period of fourteen months the area was grazed with sheep on thirteen occasions. In no grazing did they show preference for any particular white clover strain.

It might have been thought that symptoms of HCN poisoning could have been produced in sheep grazing the high-glucoside clover. A pure stand of this clover in a ¼-acre paddock was intermittently grazed by sheep over a period of 21 months. Although they usually grazed the clover readily, at no time were any deleterious effects on them observed.

It was noticed that rabbits, which occasionally gained access to white clover plots and single plant areas, showed a distinct preference for glucoside-free plants. Damage to the leaves of glucoside-free plants caused by slugs (*Agriolimax* spp.) was often severe when high-glucoside plants in adjacent plots were untouched. It is possible that establishment of a glucoside-free strain in a pasture could be severely retarded where slugs are numerous.

The Use of the Cyanophoric Character in the Certification of White Clover Strains

The "picric acid" test as developed by Foy and Hyde[4] is used in the certification of white clover seed in New Zealand to distinguish between strains and to indicate contamination in superior strains. For the test 50 eight-day-old seedlings are placed in a small test tube, a drop of toluene or chloroform is added, a strip of picrate paper is held in the upper part of the test tube by means of a rubber stopper and the tubes are incubated at 30°c. for two days. Tests are carried out in triplicate. They are classified on a 0-6 scale based on the intensity of colour change in the picrate paper which progresses from lemon yellow to a deep reddish brown. The test will be referred to in this paper as the "picric acid test" to distinguish it from the "picrate test" on leaves of individual plants. By the use of the picric acid test strains can be identified in a matter of days rather than the months required when plot tests are employed.

In Table V is shown the relationship between the picric acid test and the picrate reactions of the individual plants in a line. These reactions were obtained by carrying out picrate tests on the leaves of individual seedling plants by the modified test as described earlier in this paper. On the reaction in these tests a plant could be classified as containing both enzyme and glucoside, enzyme only, glucoside only, or neither. In those tests which showed the presence of glucoside the intensity of the reaction was recorded on a 1-6 scale to obtain an approximate estimate of the relative percentage of glucoside present. Melville *et al.*[9] have shown that this test is roughly quantitative. In Table V this grading has been abbreviated to "slight," "moderate" and "intense" classes. Thirty-six lines with picric acid tests ranging from 1 to 6 are compared. In most cases a sample of 50 plants has been examined.

The picric acid reaction of a line depends on the number of individuals containing glucoside and the amount of glucoside in those plants. On the former criterion the lines tested can be divided into two distinct groups:—

(1) Those with a picric acid test of 1 to 3 which (with the exception of C837) contain 34 to 62 per cent of individuals with glucoside.

(2) Those with a test of 4 to 6 which contain 69 to 96 per cent of positive individuals.

The data in Table V is shown in graphical form in Fig. 1 where both number of positive plants and amount of glucoside in these plants is taken into account. The relative percentage of glucoside in each line

TABLE V. THE PERCENTAGE OF PLANTS WITH AND WITHOUT GLUCOSIDE IN WHITE CLOVER LINES OF VARIOUS PICRIC ACID REACTIONS

Line No.	Picric Acid reaction	Percentage plants with glucoside				Percentage plants without glucoside
		Slight reaction	Moderate reaction	Intense reaction	Total	
C834	1	10	20	10	40	60
C835	1	22	14	8	44	56
C836	2	38	20	4	62	38
C837	2	10	46	30	86	14
C838	2	22	26	6	54	46
C839	2	8	14	22	44	56
C840	2	26	10	2	38	62
C841	2	14	18	18	50	50
C842	2	14	34	12	60	40
C843	2	9	23	19	51	49
C844	2	28	12	6	46	54
C845	3	38	6	2	46	54
C846	3	16	26	24	66	34
C847	3	24	18	14	56	44
C848	3	42	6	2	50	50
C849	3	26	26	12	64	36
C850	3	16	28	2	46	54
C851	3	27	25	8	60	40
C852	3	24	8	2	34	66
C853	3	15	13	17	45	55
C854	3	16	16	20	52	48
C855	4	0	16	76	92	8
C856	4	4	20	64	88	12
C857	4	0	15	75	90	10
C858	4	4	14	51	69	31
C859	4	4	22	58	84	16
C860	5	10	28	58	96	4
C861	5	10	32	44	86	14
C862	5	8	32	40	80	20
C863	5	8	36	44	88	12
C864	5	8	30	42	80	20
C865	6	2	22	56	80	20
C866	6	2	42	44	88	12
C867	6	6	24	40	70	30
C868	6	0	22	74	96	4
C869	6	6	20	56	82	18

has been calculated from the number of plants containing glucoside and the percentage of glucoside in those plants as indicated by the intensity of the picrate reaction. The percentage of glucoside per plant has been calculated from the intensity of the picrate reaction in accordance with the table given by Melville *et al.*[9] in which the intensity as obtained by the method used here is related to the percentage of glucoside shown by quantitative chemical analysis.

With one exception (C837), the picric acid test clearly distinguishes between lines with a test of 1-3 and those testing 4-6. It does not, however, differentiate the classes within these groups. There is no clear distinction between lines with a test of 1, 2 or 3, or between those testing 4, 5 or 6. As the test is at present used, all lines in the former group and some in the latter would be rejected from certification. On the results of the picrate tests on individual plants it does not appear that the distinctions between reactions of 4, 5 and 6 are warranted.

The Use of the Picric Acid Test to Detect Contamination in Bred Strains of White Clover

The picric acid test was originally used in New Zealand to distinguish between the New Zealand No. 1 strain of white clover described by Davies and Levy[10] and the agronomically poor strains of New Zealand white clover. The No. 1 strain was shown by Foy and Hyde[4] to give a strong picric acid reaction whilst the reaction with the poor strains was weak.

A pedigree strain of white clover has now been produced which has largely replaced the No. 1 strain in certification. It was bred from plants selected largely from the No. 1 strain and is likewise high in cyanogenetic glucoside. With this strain now being widely grown the picric acid test is being used not only to distinguish it from the poor strains low in HCN but also to detect contamination by inferior agronomic types. It is important to know to what extent the picric acid test fulfils this latter requirement. To provide information on the efficiency of the test in detecting contamination in lines of high glucoside content and in those without glucoside the following experiments were carried out. The tests were made at the Official Seed Testing Station using their standard picric acid test in which 50 eight-day-old seedlings per test are used, and the tests are made in triplicate.

Contamination of High-Glucoside White Clover Lines with Glucoside-Free Individuals

Four high-glucoside lines were contaminated with seedlings of a glucoside-free strain in proportions ranging from 2 to 64 per cent. The colour of the bottom and top ½-inch of the picrate paper was recorded by comparison with plates in the Ostwald Colour Album[11]. In all four clover lines no change in the intensity of colour of the picrate paper could be detected below 24 per cent contamination. A typical colour change is shown in Table VI.

TABLE VI.: CHANGES IN THE PICRIC ACID REACTION FOLLOWING CONTAMINATION OF A HIGH-GLUCOSIDE WHITE CLOVER LINE WITH VARIOUS PERCENTAGES OF GLUCOSIDE-FREE INDIVIDUALS

Percentage Contamination	Colour of picrate paper * Bottom ½ in	Top ½ in
0	6 pe	3-4 la
2	"	"
4	"	"
8	"	"
12	"	"
16	"	"
24	5 nc	3 la
32	"	3 la
64	"	2 la

* Ostwald colour chart.

Contamination of a Glucoside-free White Clover Line with High-Glucoside Individuals

In this experiment the line contaminated was free from glucoside but contained enzyme. The contaminants were seedlings from a plant homozygous for glucoside. The colour changes following the various degrees of contamination are shown in Table VII. In this case contamination is much more readily detected than in high-glucoside lines, for contamination as low as one seed in fifty is discernible.

TABLE VII. CHANGES IN THE PICRIC ACID REACTION FOLLOWING CONTAMINATION OF A GLUCOSIDE-FREE WHITE CLOVER LINE WITH VARIOUS PERCENTAGES OF INDIVIDUALS CONTAINING GLUCOSIDE.

Percentage Contamination	Colour of picrate paper *	
	Bottom ½ in	Top ½ in
0	1 la	1 la
2	2 ia	1 la
4	3 la	1 la
8	3 la	2 la
12	3 la	2 la
16	4 la	2 la
24	4 la	2 la
32	5 nc	2 la
64	5 pe	3 la
100	6 pc	4 la

* Ostwald colour chart.

DISCUSSION

The Origin of New Zealand Strains of White Clover

The cyanophoric properties of New Zealand strains of white clover provide some indication as to their origin.

White clover in New Zealand is extremely variable. The predominant type when Davies and Levy[10] carried out their survey was the "stubble" or "New Zealand Dutch" type which is very similar to the cultivated European or "Dutch" white clover in morphological, agronomic and cyanophoric properties, although somewhat superior agronomically to the latter. This New Zealand type is short-lived, low producing, free flowering and very weakly cyanogenetic. In contrast the New Zealand No. 1 type is persistent, highly productive, large-leaved with long petioles and strongly spreading stolons, and is strongly cyanogenetic. Between these two extreme types there are numerous intermediates.

The evidence adduced by Davies and Levy as to the origin of these New Zealand strains strongly supports their contention of ecotypic selection following differences in climate, soil fertility and farming

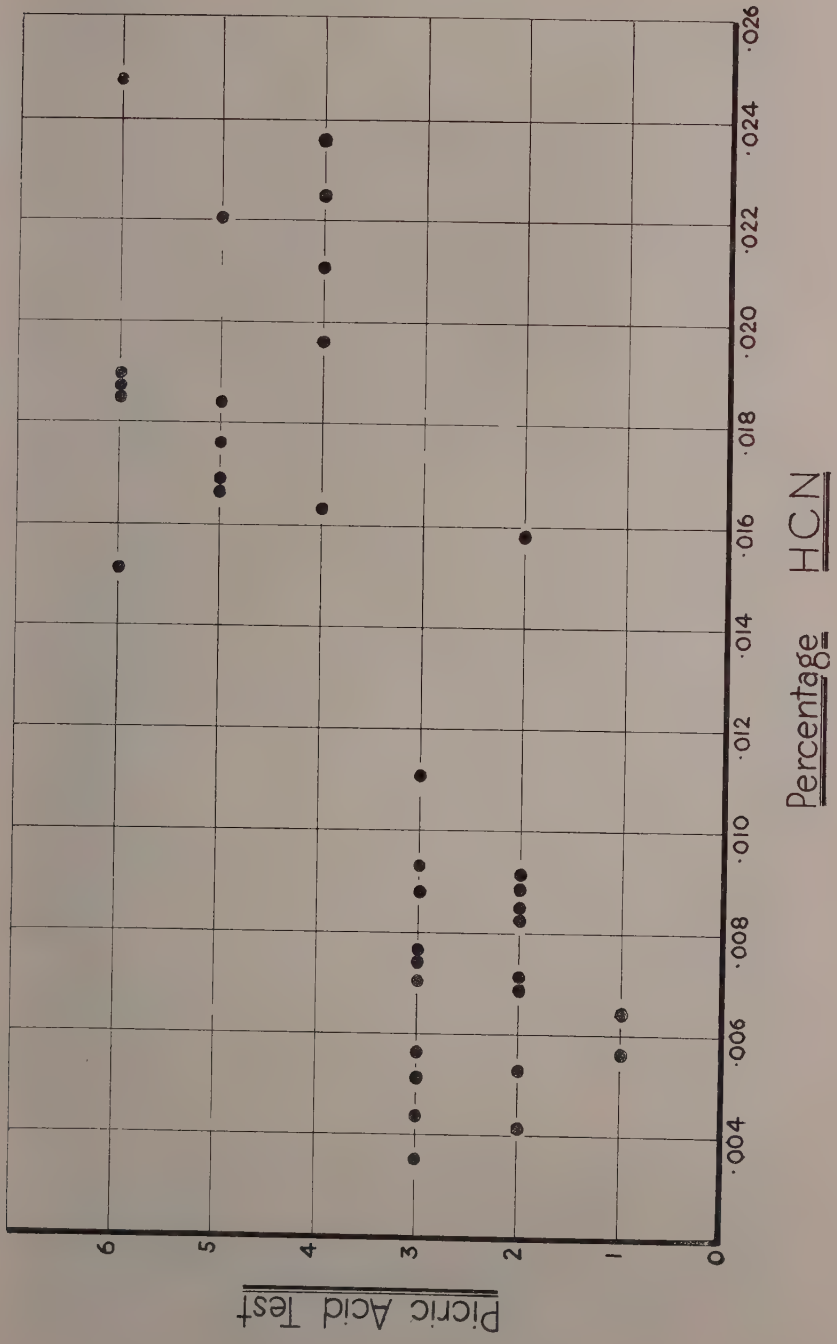
practices. For instance, the "stubble" type was characteristic of the arable regions of Canterbury which favoured the dominance of a free-seeding annual type of clover. The No. 1 strain, on the other hand, was found only in restricted areas of relatively high soil moisture and fertility, and under a system of lax grazing management favourable to the dominance of a vigorous tall-growing clover, and unfavourable to the development of weakly growing types and those which rely on annual reseeding for their perpetuation in the sward.

White clover is not endemic to New Zealand but was introduced to the country mainly from Europe within the last century. The bulk of the seed imported was probably of the common European cultivated or "Dutch" type which contains neither enzyme nor glucoside, although seed of Kentish wild white clover which is moderately cyanogenetic has probably also been imported. It is very improbable that the strongly cyanogenetic New Zealand No. 1 type originated by ecotypic differentiation from the non-cyanogenetic "Dutch" clover. However, white clover lines containing strongly cyanogenetic individuals have probably been imported in the past to New Zealand. Williams[12] located in Western France a strongly cyanogenetic white clover which was also similar morphologically to the New Zealand No. 1 strain. It is probable that the latter owes its origin largely to plants originating from such imported lines. Such individuals would be favoured by the environmental conditions in which the New Zealand No. 1 strain was found, and by ecotypical selection in this environment would tend to predominate. On the other hand, the arable farming regions of most of the South Island would favour the predominance of the free seeding "Dutch" type. This strain, harvested in the arable regions of Europe, would undoubtedly form the bulk of the seed originally imported into New Zealand. It is not surprising, therefore, that at the time of Davies and Levy's survey the great majority of the white clover lines closely resembled the European cultivated white clover both morphologically and in cyanophoric properties. The high-glucoside No. 1 strain, on the other hand, would be developed only where there was an original plant population containing a proportion of vigorous highly productive individuals, as occur in the strongly cyanogenetic white clover described by Williams, and in regions ecologically favourable to the dominance of this biotype.

The Picric Acid Test in the Certification of White Clover in New Zealand

The New Zealand No. 1 strain of white clover was found by Davies and Levy in only 4 per cent of the seed lines harvested at the time of their survey, occurring in only very restricted localities in Hawkes Bay and Canterbury. Fields in which the strain occurred were recorded as "mother" areas on the inauguration of the white clover certification scheme, and all certified seed originated therefrom. As this No. 1 strain was high in glucoside, and as it was the foundation of all certified seed of "natural" strain, the picric acid test proved reliable in distinguishing the certified strain from the ordinary New Zealand or "Dutch" types.

More recently a pedigree strain has been produced by selection and breeding with plants from the No. 1 strain. The pedigree strain, also high in glucoside, has now very largely replaced the "natural" No. 1 strain in certification. Hence the requirement has changed from distinguishing between natural strains to the detection of contamination in the pedigree strain in the various stages of increase from nucleus seed.


Picric Acid Test
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Percentage HCN

Contamination in a seed crop of white clover is due mostly to "volunteer" clover which establishes and produces seed in the crop, although a small percentage may be due to cross pollination from plants outside the crop. As shown by the data in Table VI the picric acid test detects only relatively large contamination in a high-glucoside line such as the pedigree strain. Admixture of glucoside-free individuals is not detected under 24 per cent, and the percentage would be greater if some of the contaminants contained glucoside. Even in the poor New Zealand strains of white clover about 50 per cent of the plants may contain glucoside. Contamination of a high-glucoside line with such strains would probably not be detected unless it was even higher than 24 per cent. It is clear that the test is not sufficiently sensitive in detecting contamination in high-glucoside lines of white clover.

On the other hand, contamination of a glucoside-free strain by individuals containing glucoside can be detected in an amount as low as 2 per cent. However, contamination by the uncertified New Zealand strains containing 50 per cent glucoside-free individuals would not be revealed at this low level. Nevertheless, the percentage would be much below that which could be detected in a high-glucoside line contaminated by similar uncertified lines.

The picric acid test as at present used readily distinguishes the high-glucoside certified strain from the low-glucoside uncertified strains or the cultivated "Dutch" white clover. These latter would also be readily distinguishable from the glucoside-free strain containing enzyme if a modification of the test were used. The "Dutch" strain contains neither glucoside nor enzyme and therefore gives a negative test. By the addition of lotaustralin to the test on this strain a negative reaction would still be obtained, whereas the reaction would be positive in the strain containing enzyme.

Because of the greater accuracy with which the glucoside-free strain could be certified, it might be considered advisable to use it to replace the present high-glucoside pedigree strain in certification. But since the latter was first released into commerce in 1939 the quantity of seed harvested has increased to such an extent that at present it comprises almost 60 per cent of the white clover seed harvested in New Zealand. In the 1946-47 season, of 2,600 tons harvested, 1,500 tons were certified, and the great bulk of this was of pedigree origin. To replace this high-glucoside strain by a glucoside-free strain in order to gain the advantage of a more precise certification test would create wide disorganisation in the white clover seed industry. Nevertheless, the change would enable white clover certification to be based solely on a simple and rapid laboratory test. Field inspections of crops and plot trials of seed, which are now used in conjunction with the picric acid test for the higher certification grades, could be dispensed with. On the other hand, if the present high-glucoside pedigree strain of white clover is still used as the basis of certified seed such tests should be retained as a safeguard rather than rely solely on the picric acid test in the certification of white clover in New Zealand.

Should a strain additional to the present pedigree strain be produced to fill some particular requirement it would then be clearly advantageous in its certification if it were free from glucoside and homozygous for the enzyme. It could be distinguished by a simple laboratory test from the

high-glucoside strain, and from uncertified strains. Moreover, the degree of contamination by these strains could be easily and fairly accurately determined.

The Cyanogenetic Glucoside and Animal Health

There does not appear to be any danger in the use of a high-glucoside strain on the score of HCN poisoning. There have been no recorded instances in New Zealand of stock being poisoned by high-glucoside white clover, nor does there appear to be any effect on stock thrift when such clover is a major constituent of a pasture. In the palatability trials described in this paper, sheep grazed high-glucoside clover just as readily as glucoside-free clover when grown either as a pure stand or in combination with perennial ryegrass. Clarke[13] carried out grazing trials in which he compared the effect on ewes and lambs of high- and low-glucoside white clovers in ryegrass-white clover pastures. No difference between effects of the clovers on the thrift of the ewes and lambs grazed continuously and fed to appetite was observed. Pastures containing the high-glucoside pedigree strain of white clover showed no ill-effects on thrift or production in ewes confined to these pastures for four years.

From trials in which free HCN, lotaustralin and high-glucoside white clover were introduced into the rumen of sheep by means of a permanent rumen fistula, Coop and Blakley[14] determined the rate of hydrolysis of the glucoside, the rate of absorption of the HCN, and the rate of detoxication. Reviewing the factors which determine death from HCN poisoning, they consider[15] that under normal farming conditions where clover may at times constitute up to 60 per cent of the pasture, mortality from HCN poisoning would be widespread if the HCN content of the clover was as high as 0.09 per cent. As the maximum HCN content of the pedigree strain of white clover is of the order of 0.03 per cent there is a very wide safety margin.

There may, however, be other effects of HCN in white clover which would render it advisable to use a strain free from the cyanogenetic glucoside. For instance, Ferguson[16] has shown that white clover juice inhibits peristalsis in isolated rabbit intestines. Evans and Evans[17] have confirmed this and stated also that white clover juice inhibits the ruminal movements of live sheep. They consider that the inhibiting agent is HCN, and suggest that it may be a contributory factor in bloat in ruminants. Should such prove to be the case, strains of clover free from HCN but with the agronomic characters of those already in commerce could readily be produced by plant breeders.

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FLUE-CURED TOBACCO

VI. PRODUCTION OF CARBON DIOXIDE AND ASSOCIATED CHANGES IN CHEMICAL COMPOSITION DURING COLOURING

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Summary

Individual leaves of Harrison's Special variety of tobacco were cured in the laboratory at 32°-39°C.

Determinations of over-all loss, water lost, and carbon dioxide produced by respiration were carried out periodically.

Analysis of uncured and cured leaves revealed that large increases in reducing sugars, sucrose and water-soluble nitrogenous compounds, accompanied by a great reduction in starch content, occurred during curing.

The rate of respiration was approximately 5 mg of carbon dioxide per gram of dry matter and was proportional to the protein-nitrogen content of the leaf.

The lower the percentage hydrolysis of the starch the greater was the hydrolysis of protein. Soluble sugars were highest where hydrolysis of protein was low.

Sixteen atoms of carbon were respired for each atom of nitrogen (as protein) that was hydrolysed.

Very satisfactory agreement between determined and calculated losses of dry matter during curing was obtained from the carbon dioxide and hydrolysed-nitrogen figures. Losses of starch were, however, in several cases, in themselves sufficient to the account for the increases in soluble sugars and losses of dry matter.

Introduction

Until comparatively recently, detailed examinations of the quantitative changes in the weight relationships between loss of moisture and dry matter together with the related changes in chemical composition of tobacco leaves during curing by artificial heat ("flue-curing") do not appear to have been published. There is now available, however, a useful body of information on the progressive losses of water from the leaves at the various stages of the curing process, but in this paper only those results pertaining to the first stage of low-temperature and high humidity conditions in the kiln will be discussed. Zaporojanu[1] reported that during curing about 95 per cent of the loss in weight is water associated with about 4 per cent as loss of dry matter. About the time of yellowing of the tips and edges of the leaves there is an intensification of the rate of respiration and of evolution of carbon dioxide. At the end of this stage, 40 per cent of the water and 8-9 per cent of the dry matter of the leaf had been lost. By the time colouring was completed about 65 per cent of the original quantity of water present and 17-18 per cent of the dry matter had disappeared from the leaves. In the later stages of colouring the rate of evolution of carbon dioxide decreased somewhat.

It has been demonstrated by several workers that during the colouring stage of curing there are developed appreciable amounts of reducing sugars and sucrose. For example, Trifu[2] states that in the early stages monosaccharides predominate, but later they are replaced by sucrose.

He claims that sucrose formation occurs only below a certain relatively low moisture content of the leaf. This sequence does not appear to have been obtained under American conditions of curing. Thus the United States Department of Agriculture reported that in their experiments starch was hydrolysed to sucrose and monosaccharides, and that subsequently the sucrose was converted to reducing sugars[3].

Not only are there changes in the carbohydrates during curing but the proportions of protein and non-protein nitrogen also vary appreciably. Thus Neagu found protein-N to decrease by as much as 50 per cent with an accompanying increase of soluble nitrogen[4]. Other workers [5, 6] have noted this conversion of water-insoluble (protein) nitrogen to water-soluble forms. These changes appear to be confined to the low-temperature ranges of the curing process, i.e. the period when the living processes can operate.

Losses of dry matter occurring during the curing of tobacco leaf are due to the respiration of the leaves. It is not clear from just what sources the carbon dioxide evolved is derived. There is the possibility that the ultimate source is carbohydrate. But since digestion of proteins to simpler nitrogenous compounds also takes place, the respiratory process is probably complex, involving not only carbohydrates but also nitrogenous compounds. It is not impossible also that organic acids may be concerned in the reactions. In the experimental work described in this paper the losses of weight and the evolution of carbon dioxide under conditions comparable to those of the early stages (colouring) of flue-curing of tobacco leaves will be described. An attempt will be made to relate the amounts of carbon dioxide produced to the losses of dry matter and to the changes in chemical composition that occur during the curing of the leaves. This paper is offered also as a contribution to the fulfilment of "the desirability of further detailed investigation of the behaviour of carbohydrates of tobacco leaves for some 40 hours after the time of picking in order to discover the source of the increased quantity of soluble reducing substances . . . . ."[7] during the curing of tobacco.

Experimental Procedure and Results

Leaves of the Harrison's Special variety (Strain 215 of the Tobacco Research Station, Umukuri, Nelson) were obtained from plants grown in river sand in large cylinders embedded in the ground at the Cawthron Institute. Various fertilizer treatments were used but these are not taken into account in the present experimental work. Because only one leaf could be used in the experimental set-up it seemed to be desirable to take three successive leaves as closely comparable as possible from a given plant for each experiment. These are called top, middle and bottom leaves in the following descriptions of the experimental data. Only the middle leaf was cured. Weighing of the three leaves, to 0·01 g, was carried out within 10 min of harvesting and the test leaf was in the container in the thermostat within 15 min of harvesting. The other two leaves of each harvest were immediately dried by hot air at about 55°C. Within 20-30 min, the blades were brittle-dry but the midribs took some hours to dry. A total drying period of 16-24 hr was employed. The dried leaves were weighed and ground finely for subsequent analysis. Harvesting was done at 9-10 a.m. or at about 2 p.m. only on sunny days. The weather conditions previous to harvesting were noted.

The test leaf was held freely suspended in a large bottle in a thermostat maintained at 32°c-39°c in different experiments. Through this bottle, air, dried by passage through a concentrated sulphuric acid bubbler and a tube containing anhydrone and warmed by mixing in a smaller bottle inside the thermostat, was drawn at a rate measured by a calibrated capillary-tube flow-meter. Air entered the bottle at the top and was withdrawn from near the bottom, then passing through weighed tubes containing : (1) concentrated sulphuric acid ; (2) anhydrone ; (3) soda-lime ; and (4) anyhdrone before passing to a filter pump with a sulphuric acid backing-tube to prevent moisture reaching the last tube of anhydrone.

It was thus possible to obtain periodic records of overall losses of weight, loss of water, and weight of carbon dioxide evolved during respiration of the leaf. After the experimental leaf was fairly well coloured the experiment was stopped, the leaf was rapidly dried, weighed and prepared for analysis. Moisture determinations on the ground leaves were made at once to allow calculation of the dry matter content.

Analytical work carried out later consisted of determination of : (1) reducing sugars and sucrose contents, using Somogyi's reagent[8] ; (2) starch content by the method of Pucher *et al.* [9]; (3) total nitrogen (including nitrates) and protein-nitrogen from the residue insoluble in water at 85°c.; (4) total ash; and (5) alkalinity of the ash to methyl orange and phenolphthalein, expressed in milli-equivalents per 100 g of dry matter. By precipitation of the total sulphate from the alkalinity determination, after fuming-off with excess of sulphuric acid, it was possible to calculate the number of milli-equivalents of bases in combination with inorganic acids. Alkalinity, less that due to phosphate, has been considered to be equivalent to bases in combination with organic acids. All analytical data in this paper refer to the whole leaves, lamina plus midrib.

Data for the weights, percentages of dry matter, nitrogen, protein-nitrogen and ash, and weight of dry matter per leaf, together with associated data for the individual leaves used in four experiments are set out in Table I. A preliminary trial (Expt. I) is not reported.

Difficulties were encountered in obtaining sets of leaves such that the middle leaf was truly intermediate between the top and bottom leaves. Where there was a somewhat wide variation in the weights of the leaves and where the percentages of dry matter determined directly on the top and bottom leaves varied appreciably, it has seemed best to use the data for the leaf nearest in size to the middle leaf. This applies particularly to the calculation of the original dry matter content of the middle leaf. Just how great an effect a relatively small difference in the percentage of dry matter will have on this calculation can be illustrated from Expt. III. If the calculation is made on the basis of the figure for the percentage of dry matter in the top leaf, it would appear that 4·028 g of dry matter was present in the middle leaf when the experiment began ; if, however, the figure for the bottom leaf is used, then the original dry matter content would be 4·144 g. It will be seen later that this sensitivity to uncertainty in the weight of dry matter is an important complicating factor in dealing with some of the derived data.

The data reveal that there were no very great variations in the percentages of dry matter in the leaves. There were, however, appreciable differences in the percentages of nitrogen, and there were some differences between the several harvests for the proportion of the total

TABLE I. DATA FOR FRESH WEIGHT, DRY MATTER, NITROGEN AND ASH CONTENTS OF LEAVES.

Expt No.	Leaf Position	Fresh Weight (g)	Dry Matter (%)	Dry Matter per leaf (g)	Total Nitrogen (%)	Protein-Nitrogen (%)	Ratio of Protein-N Total-N (%)	Total Ash (%)
II	Top	28.80	22.20	6.387	2.473	1.540	62.3	13.40
	Middle	24.50	22.05	4.665 (5.056)	2.620 (2.418)	1.152 (1.487)	44.0	11.61 (10.72)
	Bottom	28.50	21.90	6.238	2.252	1.366	60.7	12.75
III	Top	20.07	22.45	4.505	1.723	1.292	75.0	9.93
	Middle	17.94	22.45	3.634 (4.028)	1.585 (1.430)	0.880 (1.072)	55.5	12.36 (11.15)
	Bottom	27.05	23.10	6.247	1.548	1.053	68.0	9.56
IV	Top	28.95	23.50	6.807	1.912	1.263	66.0	12.88
	Middle	31.68	22.95	6.448 (7.270)	2.233 (1.980)	1.000 (1.307)	44.8	12.98 (11.51)
	Bottom	25.15	22.40	5.630	1.918	1.260	65.7	10.28
V	Top	40.33	21.50	8.669	2.399	1.397	58.2	14.40
	Middle	42.55	21.50	7.552 (9.148)	2.642 (2.182)	0.850 (1.270)	32.2	15.14 (12.51)
	Bottom	34.29	20.4	7.005	2.134	1.172	54.9	14.49

Note: Figures in brackets are corrected to the original dry-matter content before curing of the leaf.

Notes on leaves of Experiments II to V:

Expt II: Leaves taken at 11.15 a.m. on a fine sunny morning after two overcast days; the day immediately preceding sampling was wet. From about the middle of plants receiving extra potash in the fertilizer.

Expt III: From a high-potash plant sampled at 1.50 p.m. on a fine sunny day following two sunny days.

Expt IV: From about mid-way up a high-nitrogen plant sampled at 8.45 a.m. on a fine sunny morning following a cloudy day with only 3.1 hours of bright sunshine.

Expt V: Leaves from about one-third way up a high-potash plant; thick and very ripe leaves. Collected at 1.50 p.m. on a sunny day following a bright day and a cloudy day with 3.3 hours of bright sunshine.

nitrogen present as protein. For top and bottom leaves of a given experiment, there was generally fair agreement in the proportion of protein-nitrogen. The proportion of protein-nitrogen in the cured leaf was much lower than in the corresponding rapidly dried top and bottom leaves. Ash percentages of the cured leaves, when expressed on the original dry matter basis, are generally in the range to be expected from their corresponding uncured leaf figures. Corrections to the "original dry matter" basis have been made from data recorded elsewhere in this paper.

TABLE II. LOSSES OF WEIGHT AND OF WATER AND OF PRODUCTION OF CARBON DIOXIDE, TOGETHER WITH DERIVED DATA, DURING CURING OF LEAVES.

Expt No.	Period (hours)	Weight of leaf (g)	Overall loss (g)	Overall loss per hour (g)	Water found (g)	Carbon dioxide found (g)	Carbon dioxide per hour (g)
II	0	22.93	-	-	-	-	-
	5.0	20.84	2.09	0.402	0.797	0.1454	0.0291
	20.5	17.68	3.16	0.204	1.345	0.3513	0.0227
	26.25	17.12	0.56	0.097	0.986	0.1162	0.0186
	43.0	14.39	2.73	0.163	3.108	0.2908	0.0174
	45.5	14.11	0.28	0.112	0.272	0.0233	0.0093
	Totals	-	8.82	-	6.508	0.9270	-
III	0	17.34	-	-	-	-	-
	2	16.76	1.18	0.590	0.523	0.0360	0.0180
	18	13.01	3.75	0.234	3.687	0.3081	0.0192
	24.5	11.99	1.02	0.159	0.878	0.1130	0.0174
	41.0	9.74	2.25	0.136	2.078	0.2060	0.0125
	Totals	-	8.20	-	7.166	0.663	-
IV	0	31.68	-	-	-	-	-
	7.0	26.38	5.30	0.757	1.994	0.1934	0.0276
	24.0	21.36	5.02	0.295	3.726	0.5272	0.0310
	31.0	19.85	1.51	0.216	1.204	0.1865	0.0266
	47.75*	17.21	2.64	0.156	2.335	0.4653	0.0278
	78.75	-	-	-	4.045	0.0145	0.0021
	Totals	-	14.47	-	13.304	1.3869	-
V	0	42.55	-	-	-	-	-
	2.5	-	-	0.361	0.260	0.0691	0.0276
	19.25	-	-		2.764	0.8275	0.0494
	25.25	33.44	9.11		0.717	0.2615	0.0436
	42.25	29.38	4.06	0.239	2.729	0.7658	0.0450
	48.75	28.21	1.17	0.180	0.707	0.2312	0.0356
	66.25	24.93	3.28	0.187	1.846	0.5561	0.0318
	-	-	-	-	6.928	-	-
	Totals	-	17.62	-	15.951	2.7112	-

*Leaf was removed after this stage.

Notes on curing conditions:

Expt II. Temp.36.5°-39°C: rate of passage of air, 65 ml per min; much water had condensed in reaction bottle by end of experiment; leaf was well-yellowed at end of experiment.

Expt III. Temp.36°-37°C: rate of passage of air, 83 ml at first, reduced later to 70 ml per min; bottom of leaf had dried somewhat by end of experiment; leaf was well-coloured finally.

Expt IV. Temp.35°-36°C: rate of passage of air, 96 ml per min. for first 7 hr, later reduced to 70 ml; leaf had dried out at bottom and was well-coloured at end of experiment; condensed water on sides of bottle was removed by a stream of dry air and weighed, after removal of leaf.

Expt V. Temp.32.5°-33.5°C; rate of passage of air, 87 ml per min., reduced to 51 ml per min. towards end of experiment; leaf was well-coloured 24 hr before removal for drying; condensed water was weighed after removal of leaf.

Data for the over-all losses in weight, the weights of water collected from the air stream, and of the carbon dioxide produced, together with rates per hour for these constituents, are set out in Table II. The foot-notes record experimental conditions of temperature and rate of flow of air through the reaction chamber.

The over-all losses in weight were large and proceeded at rates which decreased with time. This is to be expected because the amount of water in the leaf will be slowly falling. The decrease in the rate of loss was, however, much greater than might be expected from the relatively small decrease in the percentage of water in the leaf, if it is assumed that all the water is in a free state. It has been suggested by several investigators that all the water in a leaf is not in the same state because the rate of loss of water varies at different stages of curing. For the data of the present experiments there is a straight line relationship over most of the curing periods between the logarithm of the relative weight of the leaf and the number of hours of curing. In the very early stages a somewhat more rapid loss occurs than later on. Attention has previously been directed to this logarithmic rate of loss[10]. The slopes of the lines, when the data are set out in the form of a graph, are in general in the relative positions to be expected from the temperatures etc. recorded in the foot-notes to Table II.

The data of Table II show that by far the greater part of the total loss of weight of the leaves is due to loss of water. Owing to condensation of moisture on the walls of the reaction bottle due to irregularities in the temperatures between night and day, in the first two experiments the weights of water experimentally determined fell considerably short of what should have been obtained. In Expts. IV and V, however, steps were taken to measure any condensed moisture, and consequently the expected and determined amounts agree satisfactorily.

Data for the over-all losses of weight and the moisture contents of the experimental leaves at the beginning and end of each experiment, together with the calculated losses of dry matter, are set out in Table III. Total production of carbon dioxide is also included.

The method of calculation used in compiling the data of Table III was as follows. Loss of water reported in Column 2 was the difference between the calculated water content of the leaf before curing and the water remaining in the leaf at the end of the experiment. Loss of dry matter (Column 5) was the difference between the calculated amount of dry matter in the leaf before curing and that found in the cured leaf. It follows that the sum of the weights in Columns 2 and 5 should equal the determined over-all loss of Column 9. The weight of carbon dioxide produced during curing has been recalculated to an equivalent weight of dry matter by a method to be described in the general discussion of the experimental data. It is apparent that the sums of the weights in Columns 2 and 4 approximate closely to the over-all loss in weight found experimentally. In Experiments IV and V, where attention was given to the recovery of condensed water, the weights of water actually determined agree fairly well with the calculated loss of water ; therefore the sums of the weights of Columns 1 and 4 approximate closely to the experimentally determined over-all losses of weight. The determined losses of dry matter, expressed as a percentage of the original dry matter, in the leaves were as follows : Expt. II, 7·7 per cent ; Expt. III, 9·8 per cent ; Expt. IV, 11·3 per cent ; Expt. V, 17·4 per cent. In some cases, therefore, large losses of dry matter occurred, but even the high figure is not beyond that found in practical flue-curing of tobacco leaf.

TABLE III. COMPARISON OF OVERALL LOSSES OF WEIGHT WITH MOISTURE LOSS AND CARBON DIOXIDE PRODUCTION.

Expt No.	(1) Water found (g)	(2) Water lost (calculated) (g)	(3) Carbon dioxide found (g)	(4) CO_2 calculated as dry matter (g)	(5) Loss of dry matter (calculated) (g)	(6) Overall loss of weight (1 + 4) (g)	(7) Overall loss of weight (2 + 4) (g)	(8) Overall loss of weight (2 + 5) (g)	(9) Overall loss of weight found (g)
II	6.51*	8.43	0.927	0.561	0.391	7.07*	8.99	8.82	8.82
III	7.17*	7.80	0.663	0.385	0.394	7.55*	8.18	8.19	8.20
IV	13.30	13.65	1.387	0.795	0.822	14.09	14.44	14.47	14.47
V	15.95	16.02	2.711	1.593	1.596	17.54	17.61	17.62	17.62

* Low values due to incomplete recovery of water

Analysis of the rapidly dried top and bottom leaves has shown that the reducing sugars (as glucose) and sucrose contents are generally low, the former ranging from 0·95 to 2·32 per cent, and the latter from 1·53 to 3·36 per cent. In the top leaves sucrose is invariably present in greater amount than the reducing sugars, but bottom leaves contained slightly more reducing sugars and less sucrose than top leaves. The sums of the reducing-sugars and sucrose contents for bottom and top leaves agree closely, however. The low sugar values for the rapidly dried top and bottom leaves show how effective was the drying procedure in reducing the effects of enzyme actions which produce reducing sugars and sucrose where the rate of drying is low. Table IV, where the analytical data for the sugar contents are set out, shows the marked increases in sugar content of the cured leaves. Except in Expt. II, the reducing-sugars content of the cured leaves is appreciably greater than the sucrose content.

TABLE IV. STARCH, REDUCING SUGARS AND SUCROSE CONTENTS * OF WHOLE TOBACCO LEAVES.

Expt No.	Leaf	Starch (%)	Reducing Sugars (%)	Sucrose (%)	Total Sugars (%)
II	Top	17.7	2.06	3.36	5.42
	Middle	0.01 (0.01)	7.30 (6.74)	8.00 (7.38)	15.30 (14.12)
	Bottom	18.2	2.32	1.89	4.21
III	Top	33.7	0.95	2.21	3.16
	Middle	3.18 (2.86)	12.50 (11.27)	10.50 (9.47)	23.00 (20.74)
	Bottom	30.8	1.65	1.53	3.18
IV	Top	25.7	1.10	1.76	2.86
	Middle	0.87 (0.77)	10.89 (9.66)	7.56 (6.71)	18.45 (16.37)
	Bottom	n.d.	1.56	1.59	3.15
V	Top	19.5	1.84	2.06	3.90
	Middle	1.28 (1.06)	11.53 (9.52)	3.56 (2.94)	15.09 (12.46)
	Bottom	17.6	1.90	1.90	3.80

Note: Figures in brackets for middle leaves are corrected to the original dry matter basis (before curing).

n.d. = not determined.

* Expressed as percentages on the dry-matter basis

When the leaves were harvested in the morning, especially after one or more dull days, it is to be expected that the starch content would be low ; conversely, for leaves harvested in the afternoon, especially following a succession of sunny days, the starch content should be high. The data for starch content in Table IV show that there was a wide range in values, namely from 17·6 to 33·7 per cent, the latter value being for Expt. III in which the leaves were harvested after two long

sunny days (11 hours bright sunshine on each day). For the other three experiments leaves were collected on fine days following one or more dull days, or those with broken clouds, and the starch contents are appreciably lower. Satisfactory agreement in the starch contents of corresponding top and bottom leaves are found. In the cured middle leaves the starch contents are generally low, about 1-3 per cent, but in Expt. II only a trace of starch was found. The sugar contents of the cured leaves are high where the original starch content was high, but the absolute values of the reducing sugars and sucrose contents individually do not appear to be directly proportional to the starch contents (compare Expts. II and V where the starch contents are nearly the same in the uncured leaves).

TABLE V. TOTAL COMBINED BASES, INORGANIC ACIDS, AND ORGANIC ACIDS.
(Expressed in milli-equivalents per 100 g. of dry matter for whole tobacco leaves).

Expt No.	Leaf	Total bases (m.e.)	Inorganic acids (less phosphate). (m.e.)	Phosphate (m.e.)	Combined organic acids (m.e.)
II	Top	322.0	69.0	13.5	239.5
	Middle	310.0 (286.0)	78.0 (72.0)	18.5 (17.0)	213.5 (197.0)
	Bottom	310.5	75.5	17.5	217.5
III	Top	284.5	71.0	16.5	197.0
	Middle	306.0 (276.0)	82.0 (74.0)	25.0 (22.5)	199.0 (179.5)
	Bottom	262.0	77.5	16.0	168.5
IV	Top	288.0	48.0	11.0	229.0
	Middle	311.5 (276.5)	68.5 (60.5)	19.0 (17.0)	224.0 (199.0)
	Bottom	272.5	60.0	15.5	197.0
V	Top	371.5	77.5	14.5	279.5
	Middle	408.0 (337.0)	97.0 (80.0)	15.0 (12.5)	296.0 (244.5)
	Bottom	369.5	88.5	19.0	262.0

Note: Figures in brackets for middle leaves are corrected to the original dry matter before curing.

Determinations of the total inorganic bases, expressed as milligram equivalents per 100 g of dry matter, together with their distribution between inorganic and organic acids, are reported in Table V. Total inorganic bases varied from 262 to 371·5 m.e. for the different leaves. In general, the data for the middle leaves correspond satisfactorily with those to be expected from the figures for the related top and bottom leaves. Inorganic acids, except phosphate, are present to the extent of about a quarter of the total inorganic bases. Phosphate is present in a relatively small amount corresponding to from 11 to 22·5 m.e. Organic acids, reported as the difference between total inorganic bases and total inorganic acids, provide the greatest part of the acids in combination with the bases, and range from 168·5 to 279·5 m.e. As with the data for the inorganic bases, the levels of the organic acids in the

middle leaves correspond with those of their companion top and bottom leaves. At the pH value of about 5·5, usually found for New Zealand tobacco leaves, some organic acids will be present in the form of acid salts, but no determinations of this portion of the acids have been made on the present samples, nor has the total content of organic acids been determined. From Garner's data[11], it would appear that variation in organic acid content during curing is relatively small, and is unlikely to directly affect the figures for loss of dry matter in the present experiments.

DISCUSSION

Data have been reported in this paper for the over-all loss of weight of tobacco leaves under certain experimental conditions. Relationships between these losses and the losses of water are set out in Table VI.

TABLE VI. RELATION OF LOSS OF WEIGHT TO WATER CONTENT OF LEAVES.

Expt No.	Overall loss as percentage of original leaf weight	Water loss as percentage of overall loss	Original water lost (%)	Moisture content of leaf		Proportion of original moisture lost during curing. (%)
				Before curing (%)	After curing (%)	
II	38.5	95.6	47.2	77.95	66.9	14
III	45.7	95.1	56.1	77.55	62.7	19
IV	45.7	94.3	55.9	77.05	62.5	19
V	41.4	90.9	48.0	78.50	69.7	11

By the time the experiments were arbitrarily terminated the over-all losses of weight ranged from 38·5 to 45·7 per cent of the original fresh weights of the leaves. Of these losses, 90-95 per cent consisted of water, in confirmation of the amounts stated by Zaporojanu[1]. Also, these losses of water represented 47·2-56·1 per cent of the original moisture in the leaves, this being approximately the same as has been reported by Zaporojanu. Moisture contents of the leaves did not fall greatly, considering the large total losses in weight, during the experiments. This is in keeping with results obtained previously[10] for experimental curings in a commercial-sized kiln. The fall in moisture content ranged from 11 to 19 per cent of that originally present. The moisture figure at the end of the experiment is an average one for the whole leaf ; the tip portions of the leaves were drier that the main body on completion of each experiment, so that the water was not uniformly distributed. The difference figures reported for water removed during an experiment, represent more than just the residual water that has been in the leaf during that experiment ; they will include a certain amount derived from oxidation of dry matter by respiration. On the other hand, some water will be required in the hydrolysis of protein to simpler compounds and in the hydrolysis of starch and sucrose to simpler sugars. Just what the effect of these various reactions would have on the amount of water in the leaves would be difficult to determine precisely.

Trifu[2] has stated that sucrose formation occurs only when the leaf reaches a condition of lowered moisture content. It is of interest, therefore, to examine the analytical data of the present experiments from this point of view. It appears that the increase in content of sucrose during curing, calculated on the original dry-matter basis, is the greater,

the lower the percentage of moisture in the leaf at the end of the experiment. The same relationship holds if the average moisture content over the last 24 hr of the experiment is used. It is also true that reducing sugars content is the higher, the lower the final moisture content of the leaf.

Increase in total sugar content of the cured leaf has been variable, ranging from 8·6 to 17·3 per cent, the greater part of this increase being due to reducing sugars. The amount of sugar found at any stated time will be a nett quantity from sugars formed by hydrolysis of starch and those used up in vital processes.

In spite of a large amount of work with many species, investigators have not yet been able to present a detailed system of reactions to represent the changes that occur in a leaf detached from its parent plant and held under starvation conditions, as is the case with tobacco leaves during curing. Neither have they been able to determine in just what manner the reactions are related to the evolution of carbon dioxide that occurs. From the data for carbon dioxide, the rate of evolution on both the fresh and the dry-weight basis can be calculated. In Table VII such data are set out. On the fresh-weight basis, the rate of production ranges from 0·95 to 1·50 mg per gram per hour.

TABLE VII. AVERAGE RATES OF RESPIRATION IN MG OF CARBON DIOXIDE PER GRAM OF CRUDE AND ASH-FREE DRY MATTER.

Expt No.	Period (hr)	Fresh Material	Crude Dry Matter	Ash-free Dry Matter
II	0 - 5.0	1.33	5.8	6.5
	5.0 - 20.5	1.18	4.7	5.3
	20.5 - 26.25	1.07	4.0	4.5
	26.25- 43.0	1.10	3.8	4.3
	43.0 - 45.5	0.66	2.1	2.4
	Weighted average		4.2	4.8
III	0 - 2.0	1.04	4.4	4.9
	2.0 - 18.0	1.29	4.9	5.5
	18.0 - 24.5	1.39	4.6	5.2
	24.5 - 41.0	1.15	3.4	3.8
	Weighted average		4.3	4.7
IV	0 - 7.0	0.95	3.8	4.3
	7.0 - 24.0	1.30	4.4	5.1
	24.0 - 31.0	1.29	4.0	4.5
	31.0 - 47.75	1.50	4.3	4.9
	Weighted average		4.2	4.8
V	0 - 25.25	1.21	4.5	5.2
	25.25- 42.25	1.43	5.3	6.2
	42.25- 48.75	1.24	4.4	5.1
	48.75- 66.25	1.20	4.0	4.8
	Weighted average		4.6	5.2

but most of the values, which are probably the more accurate, having been determined over a longer period of time, lie in the much closer range of 1·2-1·5 mg. The mean rates for the different periods have been calculated on the basis of the average fresh weight of the leaf for those periods, and not on the original fresh weight at the beginning of the experiment. The elapsed time between the various determinations does not permit any definite statement to be made whether these tobacco leaves varied in rate of respiration in the early stages of an experiment in a way similar to that found by Yemm for barley leaves[12]. This investigator noted that the respiration rate rose rapidly in the early stages after removal from the plants, to be followed by a marked fall to a more or less stable rate of about 0·8 mg per gram per hour for a fairly long period of time. The maximum rate was of the order of 1·5 mg. There is a suggestion in the data of Table VII that maximum rates of respiration may have occurred between 24 hr and 40-45 hr after the experiments began. This may possibly correspond to the stage of increased respiration reported by Zaporojanu[1] for tobacco leaves. Further work is required however on this phase of the curing cycle.

For the rate of respiration calculated on a dry-matter basis, two sets of data can be obtained, namely, on the crude dry-matter basis, and, more desirably, on the ash-free dry matter. There is the probability of slight error in these calculations because the precise loss of dry matter through respiration is not known at each stage. In the method of calculation employed, the carbon dioxide evolved at each stage has been converted to its starch equivalent and this has been subtracted from the dry matter. Moreover, part of the ash consists of carbonates derived from salts of organic acids. Subtracting the whole of the ash from the crude dry-matter figure, therefore, gives too low a value for the ash-free dry matter. The data of Table VII are average figures for the periods stated.

On the dry-matter basis, the rate of evolution of carbon dioxide was generally between 4 and 5 mg per gram per hour. These values may be compared with the approximate figure of 6 mg calculable from the data of Roberts[13]. Because the minerals in the leaves probably do not enter directly into the chemical reactions during respiration, it appears to be very desirable to have the rate of respiration calculated on the ash-free basis. This results in an appreciable increase in the rate figure, the increase varying with the ash content of the leaves. The range of values is now generally from about 4·5 mg to about 6·0 mg. It is noteworthy that the rate of respiration remained so steady in spite of the large changes in starch and sugar contents of the leaves.

Some workers consider that in the presence of a supply of available carbohydrates during respiration a sparing action on the utilisation of protein occurs. On the other hand, certain workers believe that protein is drawn upon for respiratory purposes right from the beginning. Examination may therefore be made of the relationship, if any, between conversion of protein to simpler compounds and rate of respiration. In the present experiments, on the fresh basis the rate of production of carbon dioxide per gram of leaf per hour is more nearly proportional to the protein-nitrogen than to the total nitrogen content of the leaf. When conversion to the ash-free dry-matter basis is made, the rate is related to the proportion of protein-nitrogen but not to the total nitrogen. For a rate of 5 mg of carbon dioxide per gram per hour, the protein-nitrogen content is approximately 1·1 per cent. This may be compared with Richards' figure of about 3 per cent of protein-nitrogen with barley leaves. The spread shown in Richards' graph, as quoted by Chibnall[14],

would however permit this rate to be associated with protein-nitrogen contents ranging from 2·5 to 4·25 per cent. Tobacco leaves of the type used in the present experiments, therefore, show a higher rate of respiration for a given protein content than do barley leaves.

By proceeding on a basis similar to that adopted by Chibnall, the data giving the production of carbon dioxide, on the basis of 1 g of crude dry matter, over the whole of the experimental period in each case, are set out in Table VIII.

TABLE VIII. AMOUNT OF CARBON DIOXIDE PRODUCED.
(Expressed as mg per gram of crude dry matter).

Expt No.	Protein-C (mg)	Respiration (weighted) data (mg)	Determined (mg)
II	47	189	183
III	30	176	162
IV	45	202	187
V	56	304	296

It is apparent from these data that, even if all the carbon in the protein that is converted to soluble compounds is oxidised to carbon dioxide, only about one-fifth of the total carbon dioxide that is formed can come from protein. Even though the protein apparently does not provide a major part of the respired carbon dioxide, it is most interesting, in view of the appreciable range in total nitrogen and protein-nitrogen contents, and in the proportions of protein that are hydrolysed in the various leaves, that it should provide such a constant proportion of the total. This becomes more readily understood when it is noted that the hourly rate of protein hydrolysis varied only from 0·63 to 0·67 per cent of the total present at the start of an experiment (see Table VIII). This may be compared with the figure of 0·3 per cent which can be calculated from the data of Vickery *et al.*[7] for leaves of a much higher nitrogen content than those used by the author. It may be noted too that the rate of respiration of Vickery's leaves correspond to only about 0·15 mg of carbon dioxide per hour per gram of fresh material at a temperature of 25°C. At the end of the present experiments, on the undried-leaf basis, the protein content was at least as high and the total nitrogen content was nearly double that of the fresh leaf when the experiments began. This does not mean, however, that the make-up of the protein in amino acids was the same at the beginning and the end of an experiment. While the present data do not deny that protein may be used in respiratory processes, they do show that the function of protein is probably linked with some other compounds in the leaf to a remarkably constant degree.

It has been shown elsewhere[6] that during the early stages of the flue-curing procedure loss of protein-nitrogen is appreciable, but is accompanied by an increase in the amount of water-soluble nitrogen. In the present laboratory experiments large amounts of protein-nitrogen have been transformed into water-soluble forms, as is shown in Table IX.

TABLE IX. HOURLY RATE AND OVERALL HYDROLYSIS OF TOTAL AND PROTEIN-NITROGEN.

Expt No.	Total Nitrogen		Protein-nitrogen	
	Hourly (%)	Overall (%)	Hourly (%)	Overall (%)
II	0.40	18	0.63	29
III	0.49	20	0.63	26
IV	0.43	21	0.67	32
V	0.39	26	0.67	44

These data show that the rate of hydrolysis of protein-nitrogen was much more constant than that of the total nitrogen. Neither hourly rate was related to the over-all percentage conversion. With these figures may be compared those calculated from the data of Garner[11], namely, 12 per cent of the total nitrogen and 21·5 per cent of the protein-nitrogen for the over-all changes for leaves taken from about the middle of the plant.

By converting the total weight of respired carbon dioxide to the equivalent amount of carbon, it is found that on a weight basis the ratio of respired carbon to hydrolysed nitrogen varied in the four experiments from 11·6 to 16·0 ; on the atom basis the ratio varied from 13·6 to 18·7, with an average figure of 15·9. Thus 16 atoms of carbon were concerned with 1 atom of nitrogen in the respiratory processes (see Table IX).

If the amounts of carbon dioxide that were found in the present experiments are converted to their equivalents of sucrose, glucose or pyruvic acid (each of these being possible substrates to be oxidised during respiration), it is found that the apparent loss of dry matter would be appreciably greater than that calculated from the moisture data ; calculated in terms of starch, the agreement is better but the figures are still too high. If, however, the carbon dioxide derived from oxidation of the residues of hydrolysed protein is subtracted from that actually found and the remainder is converted to the equivalent of starch, the calculated losses on the dry-matter basis agree closely with those determined experimentally. It is assumed, with Chibnall[14], that the protein contains 50 per cent of carbon ; a nitrogen content of 17 per cent for tobacco protein has been used. Data obtained in this manner are set out in Table X, together with other data.

These figures show that the calculated and experimentally determined losses of dry matter agree satisfactorily, except for Expt. II where an error in the final dry weight of the leaf is suspected. Whereas in the production of carbon dioxide, protein apparently provided about one fifth of the total, in the loss of dry matter, the non-nitrogenous residue can account for one-seventh of that actually found. From the data of the last three experiments, the carbon contents of the respired materials vary only from 45·9 to 46·3 per cent. If the protein residue is assumed to have a carbon content of 56 per cent (a residual molecular fragment with four carbon atoms for one nitrogen atom with a formula weight of 86 would provide this percentage) and one-seventh of the

TABLE X. COMPARISON OF CALCULATED AND EXPERIMENTALLY DETERMINED LOSSES OF DRY MATTER.

Expt No.	Protein nitrogen hydrolysed (%)	Carbon respired (%)	Calculated loss of dry matter				Loss of dry matter determined (%)	Ratio $\frac{C}{N}$ by weight	Ratio $\frac{C}{N}$ atomic
			Protein residue (%)	Starch (%)	Total (%)	All Carbon as starch (%)			
II	0.43	5.00	2.05	8.41	10.46	11.2	7.7*	11.6	13.6
III	0.28	4.49	1.33	8.26	9.59	10.1	9.8	16.0	18.7
IV	0.42	5.21	2.00	8.93	10.93	11.7	11.3	12.4	14.5
V	0.56	8.09	2.67	14.49	17.16	18.2	17.4	14.4	16.9

* Suspected to be too low.

dry matter used in respiration comes from this source, then with starch providing the remainder of the dry matter, the mean carbon content of the respired material will be 46·0 per cent. It is interesting to note that nearly the same value for the respired compounds is obtained from Vickery's leaves, analysed by Chibnall[14], from tobacco of quite a different type from that used in the present experiments. It is not to be understood, however, from the above discussion that starch was oxidised directly : the oxidation probably was through sugars produced by hydrolysis of the starch.

In all four of the present experiments there were losses of starch varying from 9·4 to 13·2 per cent to be accounted for over and above those required for the formation of the increased amounts of sugars in the cured leaves. Only in Expt. II was the supply of starch exhausted at the end of the experiment, and this may perhaps explain the aberrancy of this experiment in the relationships between sugars and protein to which attention has been drawn elsewhere in this paper. In the other experiments, from 0·77 to 2·86 per cent of starch remained. On calculating the whole of the output of carbon dioxide in terms of starch, apparent losses of dry matter greater than those experimentally determined are derived (Table X). From the data for decrease in starch content other than by conversion to sugars, there has disappeared more than enough starch to provide for the total loss of dry matter in Expts. III and IV ; there is a slight deficit for this purpose in Expt. II, (but not when protein residues are admitted as respired material), and a large deficit in Expt. V. The available analytical data do not permit of any suggestion on the possible loss of starch by transformation to compounds other than sugars. Except for Expt. V the data throw some doubt on the necessity or desirability of calculating the dry-matter losses by Chibnall's process, in spite of the very satisfactory agreement of these data with the experimentally determined losses. Starch, after hydrolysis, might disappear through reactions other than those of the respiratory processes, such as formation of organic acids, but this seems unlikely (see later paragraph).

In Table IV the data for starch and sugar contents of the uncured and cured leaves are set out. To provide the increased sugar contents approximately 50 per cent of the starch that disappeared during curing would require to be hydrolysed : the range was from 44·6 per cent in Expt. V to 55·1 per cent in Expt. II. The increase in total sugars content is directly proportional to the total loss of starch. The percentage of the total starch required for formation of sugars is inversely linearly proportional to the absolute percentage of protein-nitrogen that was rendered soluble. Except for Expt. V, the degree of hydrolysis of the starch was inversely proportional to the percentage of protein-nitrogen in the leaf before curing. It is notable that low sucrose content of the cured leaf is associated with a relatively low starch content.

In view also of the large proportionate changes in the distribution of the nitrogen fractions, it is of interest to examine the data for sugars to see if there are any relationships to be found between them and the changes in the nitrogenous compounds. Using as a measure, the increases in sugar content during processing rather than the total amounts of sugars in the dry matter, it is seen from Fig. 1 that, except for Expt. II, the increases of sucrose, reducing sugars and total sugars contents on the original dry-matter basis (i.e. before curing) are linearly inversely proportional to the percentage of the total nitrogen rendered

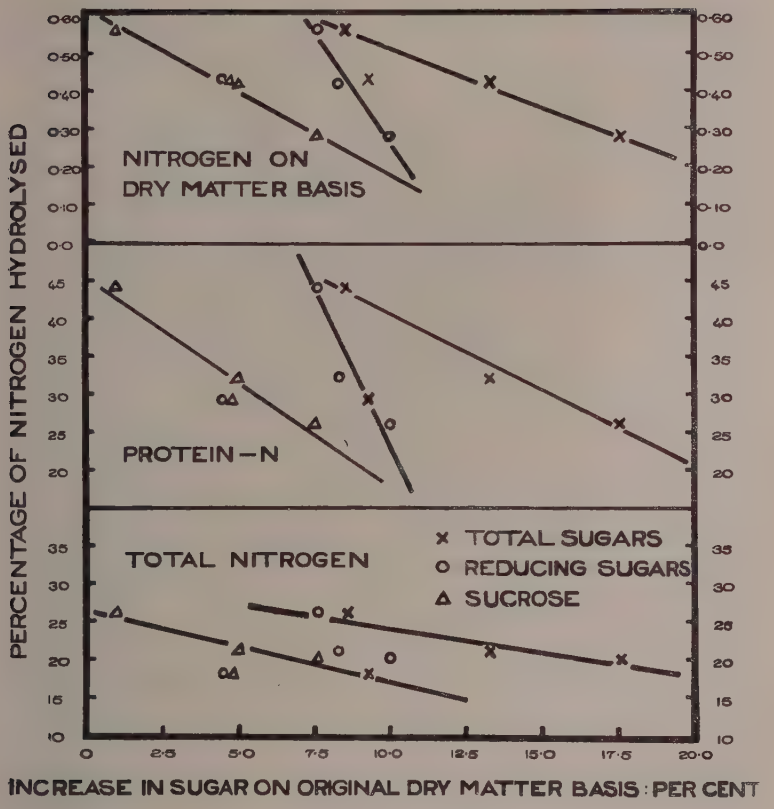

FIG. 1.—Relationships between increases of sugar contents and hydrolysis of nitrogenous compounds during curing of tobacco leaves.

soluble. When related to the percentage of protein-nitrogen rendered soluble, only the sucrose data show this linear form. The data of Expts. III, IV and V exhibit a good linear relationship for reducing sugars and total sugars, but the figures for Expt. II are aberrant. Garner's data [11] for sugar contents and protein hydrolysis, taking into account the fact that his figures refer to the fully cured leaf and the known changes in sugar content between coloured and fully cured leaves, agree satisfactorliy with the present experimental data. There is also a direct relationship between the absolute percentage of protein-nitrogen that is hydrolysed, and the amounts of soluble sugars that appear during curing. This is included in the graphs of Fig. 1. It would appear, therefore, that low sugar production, especially of sucrose, is accompanied by high conversion of protein to water-soluble compounds. This might perhaps be considered to give confirmation of the idea that protein is drawn upon by the respiratory processes to a greater degree when carbohydrate supply is low. It may be pointed out, however, that in the present work reducing sugars were present in quantity where

sucrose was low. These relationships between carbohydrates and protein hydrolysis certainly indicate that proteins are drawn into the respiratory processes in a similar manner to that suggested by Gregory.[15]

The position of the organic acids in the respiratory processes of the plant does not appear to be closely defined. Some workers consider that they occupy an important position but others think that they may not be utilized until the supply of carbohydrates has fallen to a low level. Although no estimations have been carried out in the present investigation of the amounts of the individual acids in the leaves, the data of Table V show that by far the greater part of the bases is in combination with organic acids. Unpublished figures of the author indicate that for Nelson tobacco, cured in commercial kilns, there are, during curing, no appreciable changes in the percentages of organic acids present as acidic salts. These represent about 25 m.e. of acid per 100 g of dry matter, thus being about 10 per cent of the acids in combination with bases as determined by the organic acid portion of the alkalinity of the ash. The data of Haynes and Brown[16] indicate that at pH 5·5 about 10 per cent of the total malate in a solution containing potassium malate and malic acid is present as an acid salt. On the other hand, potassium citrate solutions require a somewhat higher concentration of acid to give pH values corresponding to a similar concentration of malate. It would appear, therefore, that if malic acid is transformed to citric acid during flue-curing, the pH value of the leaf should rise. No significant variations in pH value during curing have however been found[6]. Vickery *et al.*[17] have, however, reported distinct changes in pH values of detached tobacco leaves when they were fed with potassium malate, with consequent increase in citric acid content. Some further light on the organic acid relationships may be obtained from Garner's data[11]. When correction is made to the original dry-matter basis before curing, his data show that neither malic nor citric acid has changed in amount, but that a small loss of oxalic acid, probably not beyond the experimental error, took place. It would appear therefore that in flue-cured tobacco malic and citric acids may not be metabolized to the extent that they seem to be in air-dried, cigar-type tobacco.

Summarizing, the present experimental work has shown that the greater part, or even the whole, of the loss of dry matter by respiration during the colouring stage of curing of tobacco can be accounted for by loss of starch. Increases in reducing sugars and sucrose contents are appreciable and are related to the amounts of protein undergoing conversion to water-soluble nitrogenous compounds. For each atom of nitrogen undergoing hydrolysis, sixteen atoms of carbon are oxidised to carbon dioxide. By assuming complete oxidation of the protein residues, and calculation the remaining carbon dioxide to the equivalent of starch, very satisfactory agreement between calculated and determined losses of dry matter has been found, but this does not necessarily mean that oxidation during respiration did proceed in this manner. The precise reactions taking place cannot be decided from the present data, which do, however, show that the net amounts of soluble sugars can be accounted for by hydrolysis of starch.

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SPRAY TREATMENTS FOR CONTROL OF RED MITES IN APPLE ORCHARDS

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Summary

Field trials using Selocide, HETP, BHC, parathion, Arathane, Dynone, DN III and petroleum oil for control of European and clover mites in apple orchards showed Selocide to be the most effective material tested. Ovicidal properties of Selocide were mediocre but residual toxicity gave control for several months. Two applications during or shortly after the blossom period gave control of mites for most of the growing season and the slight re-infestation which occurred in the autumn caused negligible foliage injury. Selocide showed a synergic effect in combination with sulphur. When combined with lead arsenate severe foliage injury occurred.

HETP was highly effective against adults and nymphs, but is a poor ovicide and since it has no residual toxicity trees became reinfested within a few weeks.

Parathion, Arathane and BHC all gave control of mites at the time of spraying but residual toxicity was insufficient to prevent reinfestation for more than a few weeks.

Dynone at dosages tested gave only partial control, and DN III caused foliage injury at dilutions which failed to control mites.

Summer oil was effective in killing adult and nymph stages of mites. Reinfestation occurred, but not with the same rapidity as with HETP.

Analyses of harvested fruit from trees sprayed with Selocide showed that where two applications at 1 pt to 100 gal were made before the end of October residues in fruit did not exceed 0.08 parts per million (p.p.m.) of fresh fruit weight. When applied before the beginning of February, residues did not exceed 0.3 p.p.m. From unsprayed trees fruit showed up to 0.04 p.p.m. of selenium.

INTRODUCTION

The two species of mites, *Paratetranychus pilosus* (Con. and Franz.) or European mite and *Bryobia praetiosa* Koch, or clover mite are liable to cause severe foliage injury in most apple orchards in New Zealand. European mites emerge from winter eggs during the blossom period in October while infestation by clover mites may commence even earlier in the spring. By mid-December trees are often severely infested. Foliage develops a bronze colour typical of mite injury, growth becomes stunted and fruit fails to develop normal size and colour.

Control measures commonly employed consist of a winter oil applied in the dormant period and two applications of a summer oil during the growing season in January. Because of its incompatibility with sulphur sprays required for black-spot control, summer oil cannot be used earlier in the season than January, and in consequence severe mite infestations are liable to occur before control measures are applied. The use of winter oil gives only partial control, and consequently there is need for an early summer spray treatment which is compatible with other materals used in the spray programme. In orchards where DDT is used for control of codling moth the problem of mite control is further intensified, since DDT, though ineffectual against mites, kills large numbers of predacious insects, thus allowing a rapid increase in the mite population.

With the object of improving red-mite control, field trials with several compounds have been carried out and results are reported in the present paper. Special reference is made to the use of selenium and to the toxic hazard of selenium residues in fruit.

EXPERIMENTAL METHODS

Treatments were applied to orchard trees by conventional spraying methods using a twin nozzle on a 6-ft rod at a spraying pressure of approximately 350 lb per square inch. Trials were carried out in the three main apple growing districts, Nelson, Hawkes Bay and Auckland, and included the varieties Delicious, Dougherty, Gravenstein and Jonathan. Treatments were randomized in blocks and each block was replicated at least three times. Each plot consisted of one or two trees.

Materials used are set out in Table I.

TABLE I.—LIST OF MATERIALS USED

Common or proprietary name	Active constituent	Form in which used
Selocide	selenium	solution containing 4.8 per cent selenium
HETP	tetra ethyl pyro phosphate	mixture containing 15 to 20 per cent active constituent
Parathion	di-ethyl p-nitrophenyl thiophosphate	wettable powder containing 15 per cent active constituent
Arathane	dinitro capryl phenyl crotonate	wettable powder containing 25 per cent active constituent
BHC or benzene hexachloride	γ isomer of BHC	wettable powder containing 50 per cent total BHC and 6¼ per cent γ isomer of BHC.
DN III	dicyclohexylamine salt of dinitro cyclo-hexylphenol	wettable powder containing 20 per cent active constituent
Dynone	"	solution containing unknown percentage active constituent
Summer oil	petroleum oil	mayonnaise emulsion containing 80 per cent oil of viscosity 72 sec (Redwoods I at 100°F.), 95 per cent unsulphonatable residue and viscosity index 98

The performance of different treatments was measured wherever possible by counting mites on samples of 20 leaves taken from each tree. As the season advanced it was not always possible to count the large numbers of mites present. In such cases trees were graded by observation according to degree of infestation. From general observations it was apparent that the two species of mites did not show any marked differences in susceptibility to the materials under test. Consequently, in recording, no attempt was made to differentiate between European and clover mites.

From January onwards the numbers of mites on infested trees may become reduced by causes other than spraying, e.g., by predacious insects, by depletion of food supplies in heavily infested leaves and by the washing effect of heavy rain. Because of these effects population density

when measured in the late summer is not necessarily a reliable guide to the performance of sprays applied earlier in the season. The best indication of the efficacy of treatments over the whole season is given by the degree of mite injury to leaves as shown by bronze colouration of the foliage in the late summer. In the present trials, trees were graded by observation according to degree of mite injury.

RESULTS

Field Trials

Nelson 1946-47 season: Treatments shown in Table I were applied to the Delicious variety. Results indicate that two applications of Selocide 1 pt to 100 gal applied over the blossoming period (Treatment 1) gave good control of mites until the late summer. Although increased

TABLE II. TREATMENTS AND RESULTS OF FIELD TRIAL FOR CONTROL OF RED-MITE ON DELICIOUS APPLE TREES, NELSON 1946/47 SEASON.

Quantity Insecticide per 100 gal water	Dates of applications	Average No. mites per 20 leaves 2nd Dec.	Degree of infestation**			Degree of mite injury to foliage on 2nd April
			27th Jan.	5th March	2nd April	
1. Selocide 1 pt + LS* + CS	8 and 30 Oct.	2.0	2.8	4.0	4.3	Slight to moderate
2. Selocide ½ pt + LS + CS Selocide ½ pt + LS + CS + DDT	8 and 30 Oct. 11 and 29 Nov 29 Dec. 11 Jan. and 3 Feb.	1.3	2.0	2.3	1.3	None
3. Selocide 1 pt	11 and 21 Jan.	-	3.2	3.7	4.2	Slight to moderate
4. Selocide 1 pt + summer oil ½ gal	"	-	3.0	3.3	3.0	Slight
5. BHC ½ lb gamma isomer + LS + CS	11 and 29 Nov., 20 Dec., 11 Jan., and 3 Feb.	4.3	3.2	4.3	3.5	Slight to moderate
6. Dynone ½ gal + LS + CS	8 and 30 Oct.	27.0	4.7	5.5	5.2	Moderate to severe
7. Dynone 1 gal	11 and 21 Jan	-	4.2	5.2	5.1	Moderate to severe
8. Summer oil 1½ gal	"	-	2.2	4.0	4.2	Slight to moderate
9. Check, LS + CS LS + CS + LA + HL	8 and 30 Oct. 11 and 29 Nov., 20 Dec., 11 Jan and 3 Feb.	97.0	5.2	6.0	3.6	Moderate to severe
10. Check, LS + CS LS + CS + DDT	8 and 30 Oct 11 and 29 Nov., 20 Dec., 11 Jan. and 3 Feb.	77.0	5.7	6.0	5.7	Severe
11. Check, no spray	-	54.0	5.8	6.0	2.3	Moderate to severe

** LS = lime sulphur (15% polysulphides), ½ gal; CS = 40% colloidal sulphur, 2lb; LA = acid lead arsenate, 1½ lb; HL = hydrated lime, 3 lb; DDT = ½ lb p,p' isomer in wettable powder.

* Average of grading of each tree on basis of mites per leaf, 1 = no mites present; 2 = 1 - 5 mites; 3 = 6 - 10 mites; 4 = 11 - 25 mites; 5 = 26 - 50 mites and 6 = 51 or more mites per leaf.

numbers developed in the autumn, foliage injury was only slight to moderate. Seven sprays of Selocide, ½ pt to 100 gal (Treatment 2), protected trees against mite attack throughout the season. Trees were already heavily infested by the time Selocide sprays were applied in Treatments 3 and 4. Both treatments reduced, but did not eradicate, the mite populations. The inclusion of summer oil in Treatment 4 appeared to improve performance. The use of BHC in Treatment 5 gave partial control of mites. Dynone applied over the blossom period (Treatment 6) and in January (Treatment 7) failed to give adequate control.

In Treatment 11, severe infestation of mites developed during the summer but by autumn had virtually disappeared from the trees. In Treatment 10 where DDT was used, although severe infestation also occurred and foliage injury became very severe, mites remained in large numbers into the late autumn. It appears, therefore, that in this experiment depletion of food supplies resulting from severe mite injury to foliage did not induce migration. Eradication by predacious insects appears to be the more likely explanation for the reduction in numbers of mites in Treatment 11, a process which because of the use of DDT would not occur in Treatment 10.

Nelson 1947-48 season: In Table II are shown treatments and results secured on the Delicious variety. Selocide, 1 pt to 100 gal, applied over the blossom period (Treatment 1) gave control of mites until the late summer and although trees became reinfested in the autumn, mite injury to foliage was negligible. Applications of Selocide during the summer (Treatment 2) reduced the population of mites, and prevented reinfestation for the remainder of the season.

HETP, ½ pt to 100 gal, applied at the blossom period (Treatments 3 and 4) gave highly effective control of mites at the time of spraying, but trees soon became reinfested, resulting in severe foliage damage by the late summer. As a summer spray, HETP in Treatment 5 gave effective control of adult and nymph stages of mites but failed to prevent a rapid and heavy reinfestation. Summer oil, 1¼ gal to 100 gal (Treatment 6) gave effective control of mites at the time of spraying and although the population increased later in the summer it did not become as heavy as that following the HETP applications of Treatment 5.

Nelson 1948-49 season: Treatments shown in Table IV were applied to the Delicious variety. Trees were in adjacent blocks but as different treatments were not randomized the results may be subject to some error. However, the superiority of Selocide compared with HETP in preventing reinfestation was clearly established.

Hawkes Bay 1947-48 season: In Table V are given results of treatments on the Delicious variety. Selocide, 1 pt to 100 gal, applied in Treatments 1-3 at successively later periods in the year all gave good control of mites. Until the late autumn a heavy infestation of mites was already developing before Treatment 2 was applied, and trees were showing severe mite injury where applications were further delayed in Treatment 3. When observations were made in the autumn the trees of Treatment 1 were, in consequence, showing less mite injury than either of the later treatments.

HETP, ½ pt to 100 gal, gave highly effective control of adult and nymph stages of mites at the time of spraying but trees soon became reinfested.

TABLE III. TREATMENTS AND RESULTS OF FIELD TRIAL FOR CONTROL OF RED-MITE ON DELICIOUS APPLE TREES, NELSON, 1947/48 SEASON

Quantity of Insecticide per 100 gal water	Dates of applications	Average No. mites per 20 leaves on 1 Dec.	Estimated mites per leaf on 10 Feb.
1. Selocide 1 pt + LS + CS	4 and 22 Oct.	1.2	3.0 *
2. Selocide 1 pt + CS + LA + HL	20 Jan. and 4 Feb.	-	1 to 5
3. HETP ½ pt + LS	4 and 22 Oct.	225	50
4. HETP ½ pt + CS	"	435	50
5. HETP ½ pt + CS + LA	20 Jan. and 4 Feb.	-	6 to 50
6. Summer oil 1½ gal	"	-	1 to 5
7. Check, LS + CS	4 and 22 Oct. 6 and 26 Nov. 13 Dec., 20 Jan. and 4 Feb.	342	6 to 50

Note: All plots received additional sprays as shown for check Treatment 7.

* Record taken 20 March.

TABLE IV. TREATMENTS AND RESULTS OF FLUID TRIAL FOR CONTROL OF RED-MITE ON DELICIOUS APPLE TREES, NELSON, 1948/49 SEASON

Quantity of Insecticide per 100 gal water	Dates of applications	Average No. mites per 20 leaves	
		8 Dec.	10 Feb.
1. HETP 1 pt + LS + CS HETP 1 pt	11 Nov. 23 Nov.	39.9	451
2. Selocide 1 pt + LS + CS	11 Nov.	9.8	4.5
3. Selocide 1 pt + LS + CS	28 Oct. and 10 Nov.	1.0	2.0
4. Check, LS + CS + LA + HL	At normal intervals through season.	71.0	No record.

Note: All plots received additional sprays as shown for check Treatment 4.

Hawkes Bay 1949-50: In Table VI are shown treatments and results of a trial on the Dougherty variety. Mite infestation in this trial developed slowly and it was not until January that differences commenced to show. Records taken on 24 February showed Selocide to be superior to any other treatment in preventing reinfestation. Parathion and Arathane gave partial control in the early summer, but later in the season trees became reinfested and showed severe mite injury.

Auckland 1947-48: Gravenstein apples were sprayed with treatments shown in Table VII. Two sprays of Selocide, 1 pt to 100 gal, applied during November gave control of mites throughout the summer. Slight reinfestation occurred in the autumn but caused only negligible foliage injury. HETP gave almost complete control of adult and nymph stages of mites at the time of spraying, but trees soon became severely rein-

fested. Since DDT was included in this treatment and not in check Treatment 3 it is likely that eradication of predacious insects was partly responsible for the rapid reinfestation.

TABLE V. TREATMENTS AND RESULTS OF FIELD TRIAL FOR CONTROL OF RED-MITE ON DELICIOUS APPLE TREES, HAWKES BAY, 1947/48 SEASON

Quantity Insecticide per 100 gal water	Dates of applications	Observations on mite infestation and foliage injury
1. Selocide 1 pt + CS	7 and 22 Oct.	Slight reinfestation in Autumn, slight foliage injury.
2. Selocide 1 pt + CS + DDT	8 and 30 Dec.	Medium infestation controlled medium foliage injury.
3. Selocide 1 pt + CS + DDT	15 Jan. and 5 Feb.	Severe infestation controlled severe foliage injury.
4. HETP ½ pt + CS	7 and 22 Oct.	Severe reinfestation, severe foliage injury.
5. HETP ½ pt + CS + DDT	8 and 30 Dec.	Severe reinfestation, severe foliage injury.
6. HETP ½ pt + CS + DDT	15 Jan. and 5 Feb.	Severe reinfestation, severe foliage injury.
7. Check, CS CS + DDT	7 and 22 Oct. 4 and 19 Nov., 8 and 30 Dec., 15 Jan. and 5 Feb.	Severe infestation, severe foliage injury.

Note: All plots received additional sprays as shown for check Treatment 7.

TABLE VI. TREATMENTS AND RESULTS OF FIELD TRIAL FOR CONTROL OF RED-MITE ON DOUGHERTY APPLE TREES, HAWKES BAY, 1949/50 SEASON.

Quantity Insecticide per 100 gal water	Dates of applications	Average No. mites per 20 leaves	
		4 Dec.	24 Feb.
1. Selocide 1 pt + CS	31 Oct. and 17 Nov.	5.3	16
2. 15% wettable parathion ½ lb + CS	"	6.7	361
3. 15% wettable parathion 1 lb + CS	"	5.3	320
4. Arathane ¾ lb	"	6.7	427
5. Arathane 1½ lb	"	7.3	289
6. Check, CS + LA + HL	15 and 30 Nov., 16 Dec., 7 Jan., 2 and 25 Feb.	71.0	709

Note: All plots received additional sprays as shown for check Treatment 6.

Auckland 1949-50 season: Results shown in Table VIII are from treatments applied to the Jonathan variety. Infestation by mites developed early in the season and check trees became severely infested by the end of November. However, by January the population began to disappear from all trees including checks. Consequently, results are of value only in indicating relative control in the early summer. Selocide

gave results superior to those of any other treatment. Parathion, 1 lb 15 per cent wettable powder (Treatment 4), and Arathane, ¾ lb to 100 gal, appeared to be the most effective of the other treatments.

Ovicidal Properties of Selocide and HETP

Trees of the Gravenstein variety were sprayed on 17 November 1947 with the following treatments:—

(1) Selocide, 1 pt + lime sulphur, ½ gal + colloidal sulphur (40 per cent sulphur), 1 lb to 100 gal water;
(2) HETP, ½ pt to 100 gal water;
(3) Lime sulphur, ½ gal + colloidal sulphur (40 per cent sulphur), 1 lb to 100 gal water.

On the following day leaves were picked from each treatment, the number of summer eggs counted and the leaves placed in moist chambers. In the initial count there were at least 1000 eggs from each treatment. The numbers of unhatched eggs were counted on 25 November and again on 1 December by which time all viable eggs were hatched. From Selocide-treatment 1, 35.9 per cent of eggs remained unhatched, from HETP-treatment 2, 10.6 per cent, and from Treatment 3, where

TABLE VII. TREATMENTS AND RESULTS OF FIELD TRIAL FOR CONTROL OF RED-MITE ON GRAVENSTEIN APPLE TREES, AUCKLAND, 1947/48 SEASON.

Quantity Insecticide per 100 gal water	Dates of applications	Average No. of mites per 20 leaves		
		19 Nov.	27 Nov.	8 Dec.
1. Selocide 1 pt + CS + LS Selocide 1 pt + CS	17 Nov. 26 Nov.	2.3	2.9	3.2
2. HETP ½ pt + DDT HETP ½ pt	17 Nov. 26 Nov.	0.8	0.8	440.0
3. Check; no spray	-	161.0	312.0	945.0

In addition to the above sprays, Treatment I received LS + CS + HL + LA and Treatment 2 received DDT at normal intervals during the season.

TABLE VIII. TREATMENTS AND RESULTS OF FIELD TRIAL FOR CONTROL OF RED-MITE ON JONATHAN APPLE TREES, AUCKLAND, 1949/50 SEASON

Quantity Insecticide per 100 gal water	Dates of applications	Average No. mites per 10 leaves 2 Dec.
1. Selocide ½ pt + LS + CS	28 Oct. and 11 Nov.	7.4
2. 15% wettable parathion, ¼ lb + LS + CS	"	57
3. 15% wettable parathion, ½ lb + LS + CS	"	56
4. 15% wettable parathion, 1 lb + LS + CS	"	30
5. BHC ¼ gamma isomer + LS + CS	"	72
6. Arathane ¾ lb	"	25
7. Check, no spray	-	644

sulphur was used alone, 2.8 per cent. Statistical analysis showed difference between treatments to be highly significant. Results indicated that ovicidal properties of Selocide were mediocre and that those of HETP were poor.

Synergic Effect of Selocide with Sulphur

Trees of the Delicious variety were sprayed with Selocide, with and without the addition of colloidal sulphur paste (40 per cent sulphur). The numbers of mites surviving two days later were recorded from samples of leaves off each tree. Treatments applied and results secured are shown in Table IX below.

TABLE IX.—MITES SURVIVING AFTER VARIOUS TREATMENTS

Quantity insecticide per 100 gal water	Average number of mites per leaf
Selocide 32 fluid oz	4.2
„ „ „ + colloidal sulphur 2 lb	0.5
Selocide 16 fluid oz	44.2
„ „ „ + colloidal sulphur 2 lb	4.5
Selocide 8 fluid oz	64.7
„ „ „ + colloidal sulphur 2 lb	11.8
Colloidal sulphur 2 lb	166.7
Check, no spray	167.7

Results of this trial show that the addition of colloidal sulphur improves the performance of Selocide to an extent which cannot be attributed to the sulphur. This would appear to be due to the synergic effect of the Selocide.

In several field trials with fungicides for control of black-spot, Selocide has been employed to prevent infestation by mites. It has been observed that where sulphur sprays were not used control of mites was poor compared with highly efficient control in those treatments in which sulphur sprays had been applied.

Spray Injury

The combination of Selocide with summer oil in Treatment 4 in 1946-47 season at Nelson caused slight foliage injury. When combined with lead arsenate on the Delicious variety in Treatment 2 at Nelson in 1947-48 season, Selocide did not cause foliage injury. In the following season, however, in Hawkes Bay, Selocide was inadvertently combined with mercurated lead arsenate in summer sprays on the Dougherty variety. Very severe fruit and foliage injury occurred. In Nelson in 1946-47, Selocide when combined with DDT caused slight defoliation on the Dunn's Favourite variety. Trees in the same block sprayed with Selocide plus BHC showed no sign of damage. Foliage injury from the combination of Selocide with DDT has not occurred in any other trial reported in this paper.

In the 1947-48 season at Nelson, summer oil caused partial defoliation of trees after the second oil application in Treatment 6. Since sulphur sprays were applied five weeks prior to the first oil application, injury did not appear to be due to the known incompatibility of petroleum oil with sulphur.

Tree injury did not occur in any of the trials with HETP, BHC, parathion and Arathane. Dynone did not cause damage but DN III resulted in severe foliage injury in a trial at Auckland when used at 2½ lb to 100 gal, at which dilution it gave only partial control of mites.

Selenium Residues in Fruit

Sample cases of fruit from various field trials were sent to the Dominion Laboratory, Department of Scientific and Industrial Research, where analyses were carried out for selenium residues. Fruit was picked and packed for transportation with a minimum of handling to ensure that residues would not be less than those occurring under commercial conditions of grading and packing. In the first set of analyses, total selenium was estimated, but in the later samples selenium from the skin and flesh was estimated separately. Results are given in Table X.

In no case did residues exceed 0.3 p.p.m. of fresh fruit weight, and only approached that figure when applications were made late in the summer, e.g., 15 January and 5 February in Hawkes Bay in the 1947-48 season. With two applications of Selocide, 1 pt to 100 gal, applied before the end of October the highest figure for selenium residues was 0.08 p.p.m. of fresh fruit weight. Analyses show that the majority of selenium remains on or in the skin. In the analyses made on fruit from the same trees in three consecutive seasons there is no evidence to suggest any marked build up in selenium content of fruit.

TABLE X. SELENIUM RESIDUES IN APPLES OF DELICIOUS VARIETY

Quantity Insecticide per 100 gal water	Dates of applications	No. samples analysed	Selenium parts per million of total fruit		
			Skin	Flesh	Total
Nelson, harvested 4 Mar. 1947					
Selocide ½ pt	8 and 30 Oct., 11 and 29 Nov., 20 Dec., 11 Jan., and 3 Feb.	3	-	-	0.116
Selocide 1 pt	8 and 30 Oct.	3	-	-	0.022
Selocide 1 pt	11 and 21 Jan.	3	-	-	0.178
Check		3	-	-	0.013
Nelson, harvested 16 Mar. 1948					
*Selocide 1 pt	4 and 22 Oct.	4	0.020	0.010	0.020
Selocide 1 pt	20 Jan. and 4 Feb.	3	0.187	0.060	0.247
Selocide ½ pt	4 and 21 Oct. 4 and 21 Nov.	3	0.022	0.023	0.045
* Check		3	0.007	0.007	0.015
Hawkes Bay, harvested 1 Apr. 1948					
Selocide 1 pt	7 and 22 Oct.	6	0.031	0.019	0.050
Selocide 1 pt	8 and 30 Dec.	5	0.125	0.026	0.151
Selocide 1 pt	15 Jan. and 5 Feb.	6	0.249	0.040	0.289
Check		6	0.008	0.004	0.012
Nelson, harvested 14 Mar. 1949					
*Selocide 1 pt	7 and 28 Oct.	2	0.044	0.036	0.080
*Check		2	0.022	0.015	0.037
Nelson, harvested 16 Mar. 1950					
*Selocide 1 pt	8 and 30 Oct.	2	0.033	0.020	0.053
*Check		2	0.005	0.003	0.008

* Treatments applied and samples taken from same trees each season.

DISCUSSION

Selocide: Of the materials used in these trials Selocide is the most effective. Although ovicidal properties are weak residual toxicity is high, being sufficient to kill newly hatched nymphs and prevent reinfestation of trees for several months. It is shown that one or two applications at or shortly after blossoming at dosages of ½-1 pt to 100 gal gives protection until the late summer, and although reinfestation may occur in the autumn foliage injury by mites is only slight. Where applications of Selocide are delayed until December or January control persists later into the autumn. Under these conditions, however, severe foliage injury by mites may occur prior to spraying at a time when it has an important influence on tree nutrition.

Selocide shows a synergic effect in combination with sulphur. Hoskins *et al.* (1938) have suggested that the increased toxicity of the mixture is due to chemical reaction between selenium and sulphur producing a more active compound, possibly selenium sulphide.

In combination with lead arsenate Selocide may cause severe foliage injury. Although there is some evidence to suggest that in combination with DDT slight foliage injury may occur it does not appear to be of economic importance.

The consumer hazard from toxic residues of Selocide is discussed later.

HETP: At a dosage of ½ pt to 100 gal, HETP is highly toxic to adult and nymph stages of mites but has negligible ovicidal properties. It shows no residual toxicity and consequently trees soon become reinfested particularly where treatments are applied to trees carrying a large number of summer eggs. The rate of reinfestation appears to be greater than would be expected in comparison with check trees, e.g. in the trial reported for the 1947-48 season in Nelson. It seems possible that HETP by killing insects predacious on mites allows a higher survival rate of newly hatched nymphs.

Parathion: At dosage rates of ½-1 lb of 15 per cent wettable powder, parathion kills adult and nymph stages of mites. Residual toxicity, however, is weak and trees become reinfested within a few weeks of spraying.

Arathane: Trials with this material were only of a preliminary nature. They indicate high toxicity to adult and nymph stages of mites, but fail to show control for more than a few weeks.

Dynone and DN III: In Nelson in 1946-47 season Dynone failed to give adequate control of mites at dosages employed. DN III, in which the same toxic chemical is used, caused severe foliage injury in an exploratory trial at a dosage below the level required for efficient mite control.

BHC: Results of the trial in 1946-47 season at Nelson show that BHC partially controls mites. Evidence from Auckland in 1949-50 also shows partial control but in neither case were results sufficiently favourable to suggest the use of BHC in commercial orchards.

Summer oil: From January onwards summer oil, 1 gal to 100 gal, gives control of mites equal to that of HETP and is more effective in

preventing reinfestation. Foliage injury often follows the use of summer oil and though not severe is a limiting factor in its use in commercial orchards.

Selenium residues: The main criticism of the use of Selocide on orchard trees arises from the fact that selenium is known to be highly toxic to humans. Considerable evidence has been obtained from the response of people living in certain areas of the mid-western states of the United States of America where the selenium content of soil is abnormally high. In these areas foodstuffs may contain as much as 18 p.p.m. of selenium and people living on such food develop chronic selenium poisoning. In a review of data relating to acute and chronic effects of selenium on mammals Hoskins *et al.* (1938) conclude that where the whole diet contains up to 3 p.p.m. of selenium no detectable symptoms of chronic poisoning are produced. Selenium is present in small amounts in most soils and is commonly found in foodstuffs from many parts of the world. Thus Robinson (1936) reporting on commercial samples of wheat taken from 10 different countries showed a range in selenium content of 0.1-1.9 p.p.m. From Canterbury, New Zealand, he recorded a content of 0.4 p.p.m. Analyses reported in the present paper show a natural selenium content in apples ranging from 0.01 to 0.04 p.p.m. Where two applications of Selocide, 1 pt to 100 gal, are applied before the end of October analyses reported in Table VIII show that in the crop harvested 4 to 5 months later, residues of selenium do not exceed 0.08 p.p.m. When similar sprays are applied later in the season to give an interval of 5-7 weeks from harvest residues do not exceed 0.30 p.p.m. Thus it is apparent that selenium residues at harvest time in apples sprayed under conditions of these trials are considerably less than the maximum tolerance of 3.0 p.p.m. quoted above and are less than the amount which may occur naturally in some wheat grown in New Zealand.

Analyses of fruit from trees not sprayed with Selocide show that selenium is assimilated from natural sources in the soil. Since most of the selenium applied to trees as sprays eventually goes into the soil it is possible that over a period of years the quantity taken up by trees might be increased. Analyses in three consecutive years of fruit from the same trees sprayed and unsprayed with Selocide show no trend towards increased assimilation.

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SIGNIFICANCE OF HAIRINESS (MEDULLATION) TO THE WOOL TEXTILE INDUSTRY

PART II. CORRIEDALE HOGGET WOOLS

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Summary

Two batches of 56/58s quality Corriedale hogget wool, identical in fibre fineness, length and soundness but differing in medullation by the equivalent of about 3.4 per cent of "coarse hairy fibre," have been followed with detailed observations through all stages of processing to the dyed and finished fabric. The medullation was relatively small in amount and confined mainly to the tips, and it was found almost impossible to distinguish the medullated fleeces visually.

The medullated batch gave a slightly more irregular roving and a more uneven yarn with slightly more ends down in spinning fine counts and a lower spinning limit. No differences in appearance and handle were found in either woven or knitted fabrics, and no differences of practical importance could be detected between the finished woven fabrics after dyeing by four commercial methods.

Introduction

In Part I of this series, Townend and McMahon (1944) found that neither the processing properties of sound well grown Romney wool of 48/50s quality nor the appearance and handle of fabrics made from this material were affected by the presence of medullation equivalent to about 6 per cent of coarse hairy fibre.

The present paper is an extension of the method of investigation described in Part I to the study of wools of a finer quality, namely 56s to 60s.

Experimental Procedure

Selection of Wool

It was realised at the outset that the task of finding sufficient hairy wool in the finer qualities would be a difficult one, and it was decided to select the wool from a considerable number of bales which had recently been shown for appraisement. To avoid raw material with characteristics which might interfere with effects due to medullated fibre, it was necessary to restrict the choice of wool to that which was of good staple length, sound, and of a high character or style grading. These conditions greatly restricted the amount of wool available.

It was felt that both ewe and hogget wool should be examined, because of the opinion that medullated fibre, in even small amounts, would have some effect because of the relatively fine texture of cloth manufactured from wool of the quality under discussion.

(a) *Ewe Wool*

Wool grown on 25 different properties was examined by testing in benzol at least 10 likely fleeces from each property. In all, approximately 250 fleeces were tested for medullation. Only 4 showed any quantity of medullated fibre, and in these the amount was so small that it was decided to concentrate on hogget wool.

(b) *Hogget Wool*

A considerable quantity of hogget wool was examined and, of the fleeces which were of the standard required, approximately 20 per cent showed medullated fibre. In the main, medullation was restricted to the top inch and a half of the staple and in only a very few cases did medulla extend throughout the length of the staple.

It was found that the incidence of medullation was much greater in the coarser qualities of the well grown wool, but, as with the finer wool, it was restricted in nearly all cases to the tip of the staple.

Matching

When a medullated fleece was selected, a non-medullated fleece of similar quality and grade was also selected and put aside. These fleeces were subsequently more carefully matched and any portions not up to the required standard were discarded. Shoulder, side, and britch portions of the fleece were matched separately, and before the selected wool was bulked, three staples were drawn at random to provide representative samples of shoulder, side, and britch wool for each of the two main lots, A and B. From the discarded wool, two pilot lots, of approximately 50 lb each, were retained, and these lots subsequently preceded the corresponding test lots through the initial stages of processing in order to prevent contamination.

Testing

The greasy wool was analysed for medullation, fibre length and fineness by the methods used by Townend and McMahon (*loc. cit.*). For the medullation measurements random samples were drawn in duplicate from the composite sliver. For the fibre fineness measurements, slides were prepared and measured from four separate positions on the composite sliver; 1000 fibres were measured from each fleece position. For the fibre length measurements, four separate length biassed samples were extracted by the tong method from the composite sliver from each fleece position. The average sample contained approximately 160 fibres.

A summary of the results is given in Tables I, II and III.

Statistical examination of all the fineness and length measurements showed no significant difference between Lots A and B.

Processing

It was decided to make from part of each batch a 2/2 twill serge with 2/36s warp and weft, and to put the remainder of the wool into tubular knitted underwear fabric as 1/18s yarn.

Throughout the processing, every endeavour was made to keep conditions as identical as possible for the two lots. Lot B followed immediately after Lot A on the same machines, except that, in weaving, different looms but of the same model and make were used. In scouring and piece dyeing, both lots were handled together.

By means of humidification equipment some control was exercised over fluctuations in humidity during combing, drawing and spinning. The humidity ranged as follows: drawing, 66-82 per cent R.H.; spinning, generally 65-71 per cent R.H., with occasional short intervals at 60 per cent R.H. and at 80 per cent R.H. No humidification was used in the carding shed but large variations were unlikely to have occurred during the carding of the batches.

TABLE I. - HAIRINESS

Lot A			Lot B		
Sample	Wt. of wool (lb)	Deflection per gram (cm)	Sample	Wt. of wool (lb)	Deflection per gram (cm)
Shoulder	50.5	(4.85 (5.0	Shoulder	47	(6.9 (6.45
Britch	100	(4.9 (4.9	Britch	106	(8.2 (9.0
Side	60	(4.7 (4.85	Side	58.5	(8.85 (9.1
Weighted mean		4.9	Weighted mean		8.3
Percentage Hairiness*		2.9	Percentage Hairiness*		6.3

* Equivalent percentage of coarse, hairy fibre having the same proportion, by volume, of medulla.

TABLE II. - FIBRE FINENESS

	Lot A					Lot B				
Sample	Wt.of wool (lb)	M.D.* (u)	S.D.* (u)	S.E.* (u)	Weighted mean (u)	Wt.of wool (lb)	M.D.* (u)	S.D.* (u)	S.E.* (u)	Weighted mean (u)
Shoulder	50.5	25.6	5.59	0.176	26.3	47.0	26.2	6.33	0.200	26.5
Side	60.0	26.2	6.32	0.200		58.5	26.0	7.446	0.240	
Britch	100.0	26.8	6.54	0.206		106.0	27.0	7.138	0.226	

TABLE III. - FIBRE LENGTH

	Lot A					Lot B				
Sample	Wt.of wool (lb)	Mean Length (cm)	S.D.* (cm)	S.E.* (cm)	Weighted mean (cm)	Wt.of wool (lb)	Mean Length (cm)	S.D.* (cm)	S.E.* (cm)	Weighted mean (cm)
Shoulder	50.5	14.7	3.10	0.128	14.85	47.0	13.8	3.15	0.144	14.96
Side	60.0	15.4	3.46	0.142		58.5	15.7	3.26	0.124	
Britch	100.0	14.6	3.19	0.132		106.0	15.1	3.67	0.158	

* M.D. = Mean Diameter, S.D. = Standard Deviation
S.E. = Standard Error.

Scouring

The wool was scoured in a three-bowl, harrow type set and dried in a three-tier dryer. After the bowls had been made up with fresh liquors the set was run for an hour with other wool to condition the liquors. Before Lot A was passed through the bowls, a pilot lot of about 50 lb of closely similar wool was scoured in order that any bits of wool remaining in the bowls or dryer from previous scouring might be picked up; similarly, a pilot lot preceded Lot B which was scoured immediately afterwards.

The scouring temperatures of the three bowls were 127°F, 123°F and 113°F respectively, and the approximate liquor concentrations were 0.15 per cent soap and 0.16 per cent soda ash in the first bowl, and 0.1

per cent soap and 0.09 per cent soda ash in the second bowl, while the rinse bowl had a continuous supply of fresh water. The temperature of the dryer, which delivered the wool at about 5 per cent regain, was approximately 190°F. Though this would be regarded as overdrying, both batches were given the same treatment.

The mean grease contents by two measurements on each of the scoured wools were 1.33 per cent for Lot A, and 0.95 per cent for Lot B. The yields for Lots A and B after conditioning for 36 hours, were 62.5 per cent and 63.2 per cent respectively.

Carding, Backwashing, and Combing

An emulsion of "Sulfol" batching oil, made by E. F. Houghton and Co., diluted to give an oil-to-water ration of 1 to 10, was sprayed on the two batches which were then put through a Platt's cockspur teaser (standard model). The card slivers contained about 1.7 per cent of total grease and oil as determined by extraction with carbon tetrachloride.

Prior to carding, the machine, a Platt's medium card which had been running five hours since last fettled, was cleaned down. Pilot lot A was passed through and the machine, was again rubbed down and the floor swept before carding Lot A. After the batch, the sweepings and fly were collected and weighed. A similar procedure was followed for Lot B. The pilot lots were discarded at the card sliver stage. The average carding production was 53 lb per hour for Lot A and 56 lb per hour for Lot B, and in both cases a good clean sliver was produced.

All the machinery used after the card in the production of the single and twisted yarns comprised a medium set manufactured by Prince-Smith & Stells, Ltd.

The card sliver was passed through two preparer gill boxes, then backwashed in a two-bowl machine with average liquor temperatures for the first and second bowls of 114°F and 110°F respectively, and a drying temperature of 170°F in the 9-cylinder dryer. A liquor containing 0.17 per cent of Lissapol C, and 0.09 per cent Glauber's salt was used in the first bowl, and rinsing water in the second, the bowls being made up fresh for each batch. No oil was added after the dryer because an oiling mechanism was not available.

The slivers from the backwash gill were passed through one strong box and on to the punch box where balls weighing 8 lb (approx.) were made. In combing, the feed knives were adjusted by hand, care being taken to record the settings and times, so as to be able to make the same adjustments for the second batch. At the first finishing gill, about one per cent of batching oil (Sulfol) was added as an emulsion. A top sliver weighing 259 drams per 40 yd was delivered by the second finishing gill, the balls weighing 8¼ lb.

Drawing and Spinning

After 5½ months' storage, three quarters of the tops were drawn by the Bradford system and spun into 2/36s weaving yarn and 1/18s and 1/30s hosiery yarns. Small amounts were also used for a study of the limit of spin. The theoretical drafting data on which the actual drafts were based are given in Table IV. A 3.6-dram roving was made for the weaving and hosiery yarns, and a 2-dram roving (diverted from the 10-spindle finisher) for the limit-of-spin test.

Each machine was rubbed down prior to a batch going on, and, after it had passed through, representative portions of the fly and roller waste were collected.

About 1 per cent of oil in emulsion form (Sulfol) was added to the slivers behind the can gill.

For the spinning of the weaving yarn, one side of a 92-spindle cap frame made by Hall and Stells was used for Lot A and the other side for Lot B.

TABLE IV. - DRAFTING DATA

Operation	Weight of Sliver fed to machine (dr /40 yd)	Number of Ends up	Draft	Ratch (in)
1st can gill	259	12	5.5	-
2nd can gill	565	4	5.5	-
2-spindle gill	411	3	5.5	-
4-spindle drawing	224	4	6.0	8
Weigh box	149	4	6.25	$7\frac{3}{4}$
10-spindle finisher	96	3	6.5	$7\frac{1}{2}$
24-spindle dandy finisher	44	2	7.0	$7\frac{1}{4}$
28-spindle dandy rover	12.6	2	7.0	7
Spinning 1/36s	3.6	1	6.9	$6\frac{7}{8}$

TABLE V. - PIECE SCOURING

Scour	Liquor Concentration	Average Temp. (°F)	Time (min)
1	(0.4% Teepol (0.5% soda ash	(112 (110	8 11
Rinse	. . . . .	112	6
2	0.2% soap	112	10
	. . . . .	120	25

TABLE VI. - SCOURING, CARDING AND COMBING

Material	Weights			
	Lot A		Lot B	
	(lb)	(oz)	(lb)	(oz)
Greasy wool.....	211	0	215	0
Scoured wool (from dryer)...	126	0	132	0
Sweepings and fly.....	2	11	2	11
Top.....	119	5	122	14
Noil.....	9	$8\frac{1}{4}$	9	$5\frac{1}{4}$
Tear.....	12.9:1		13.2:1	

Weaving and Knitting

After twisting and winding and the usual operations for preparing the warp, the yarns were woven on two looms made by George Hodgson Ltd. A 14/15 oz cloth was specified, 57-in wide, with a sett of 24/4 Scotch tweed, 56 ends per in and 60 picks per in. About 90 yd were woven from each batch of yarn, a record being kept of warp breakages.

The A an B lots of hosiery yarn were knitted into tubular fabric which was then scoured and finished, but not chlorinated.

Piece Scouring

A 15½-yd portion from each of Lots A and B was sewn each to a worsted piece in the grease and, with a third worsted piece, was scoured in a dolly in three drafts in about 50 to 60 gal of liquor. Brief scouring data are given in Table V. After the final rinse, the pieces were cooled off and hydroextracted.

Dyeing and Finishing

Before dyeing the pieces, small scale tests on portions of cloth from Lot B were dyed in a single-top dyeing machine (along with a ball of top) with eight different dyestuffs chosen with a view to showing uneven dyeing. As no effects attributable to hairy fibre were found, in choosing dyestuffs for the bulk dyeings recourse was made to commonly used dyestuffs dyed by typical methods.

For dyeing, each scoured piece was cut into three lengths of 4 yd, and one length of 2 yd, leaving 1½ yd in the white. One portion of A and one of B were joined to a piece of scoured worsted cloth making a total weight of 50 lb clean weight.

The composite lengths were dyed in four separate dyebaths according to the following formulæ:—

Dyeing 1: 3½ per cent Cyanine Navy Blue 2RNX, 2 per cent Coomassie Navy Blue GNS, 5 per cent mon-ammonium phosphate; mixture brought to the boil in about 1 hour and kept boiling for 2 hours; the pH of the dye liquor (at room temperature) after boiling 1 hour was 6.5, and after boiling 2 hours, 6.3.

Dyeing 2: 1 per cent Alizarine Brilliant Sky Blue B222, 15 per cent Glauber's salt, 5 per cent mon-ammonium phosphate; mixture brought to boil in 1 hour and boiled 1¼ hours; the pH of the dye liquor varied between 6.4 and 6.6.

Dyeing 3: 2 per cent Solochrome Red ER135, 15 per cent Glauber's salt, 2 per cent acetic acid; mixture brought to the boil in 1½ hours and boiled 1 hour, cooled to 180°F and afterchromed with 1.1 per cent potassium bichromate, boiling for 45 min.; pH at beginning of chroming was 5.1 and at end of chroming 5.5.

Dyeing 4: About 1 per cent of easily levelling yellow and blue dyestuffs, 15 per cent Glauber's salt, 4 per cent sulphuric acid; mixture brought to the boil in 1 hour and boiled 1¼ hours; pH of dye liquor 2.5.

After the pieces had been dyed, whizzed, and tentered, they were brushed on the back, cropped, brushed on the face and rotary pressed.

RESULTS AND DISCUSSION

Carding and Combing

No marked differences were detected between the carding performances of the two wools. The sweepings and cleanings from the card, as shown in Table VI, were very similar in composition and weight.

No differences were observed in the processing of the two lots either on the comb or on the finishing gills. Fibre length analyses of the tops revealed no significant difference between them as shown in Table VII.

The lengths of the noils compared very closely, the mean lengths of true samples (as distinct from the length biassed samples taken from the greasy wool and top) being 2.4 cm and 2.45 cm for Lots A and B respectively.

Fineness measurements on the tops are recorded in Table VIII.

The tops of Lots A and B do not differ significantly from each other in fineness.

Duplicate representative samples were taken from the card sliver, top and noil of both lots and measured for hairiness in an endeavour to find if there was any evidence of the hairy fibres having suffered more breakage than the other fibres. It is considered that the differences between the mean results of the card slivers and the corresponding tops and noils are not large enough to warrant any comment (Table IX).

Drawing and Spinning

Both wools processed equally satisfactorily through the drawing. Each lot produced about the same quantity of fly and roller waste, and these did not show any significant change in medullated fibre content at successive steps of processing.

The oil and grease contents of the rovings of Lots A and B, as determined by petroleum ether extraction, were 0.94 per cent and 0.90 per cent respectively.

The mean counts of the rovings were in good agreement with theory, being for each batch 3.6 drams per 40 yd for the heavier roving (measured on twenty-four 48-in lengths), and for each batch 2.000 ($\pm$ 0.001) drams per 40 yd of the 2-dram roving, as determined during the measurement of irregularity described below.

The irregularity of the 2-dram rovings was measured by the Cut Hank Method of Martindale (1945). With the equipment available, 100 groups of 39 one-inch lengths spaced at intervals of 27 in were weighed in the conditioning-room. Under these conditions, the standard deviations in drams per 40 yd were found to be 0.00692 and 0.00750 for Lots A and B respectively. The corresponding coefficients of variation are 13.5 per cent and 14.6 per cent. Thus the rovings of Lot B were slightly more irregular than those of Lot A.

In the spinning trials, a summary of which is given in Table X, the weaving yarn and the special spinning tests were concentrated upon. In recording ends down, only those were counted where the breakage was due to a weak place and ends down in the first 20 min were neglected. The 1/18s hosiery yarn gave a negligible number of ends down for both Lots A and B. The other results show statistically a highly significant difference in favour of the Lot A yarns, but the greater variability of the roving of Lot B offsets to some extent the probable difference in spinning properties of Lots A and B.

TABLE VII. - FIBRE LENGTH OF TOPS

Lot A			Lot B		
Sample	Mean Length (cm)	Standard Deviation (cm)	Sample	Mean Length (cm)	Standard Deviation (cm)
1...	14.6	4.0	1...	12.7	4.4
2...	12.7	4.6	2...	13.4	4.1
3...	12.5	4.1	3...	13.0	4.9
4...	11.8	4.4	4...	13.4	5.1
5...	11.8	5.0	5...	13.3	4.1
6...	11.3	4.4	6...	9.9	5.0
Grand mean (weighted)	12.30		Grand mean (weighted)	12.46	
Standard Error	0.12		Standard Error	0.15	
Coefficient of Variation	36.1 %		Coefficient of Variation	37.0 %	

TABLE VIII. - FINENESS OF TOPS

Sample	Lot A		Lot B	
	Mean Diameter (u)	Standard Deviation (u)	Mean Diameter (u)	Standard Deviation (u)
1 ...	26.4	6.8	27.2	8.0
2 ...	27.2	6.4	27.4	6.5
3 ...	27.6	7.4	27.8	7.6
4 ...	27.0	7.2	28.6	8.0
Grand Mean	27.1		27.8	
Standard Error	0.35		0.38	
Coefficient of Variation	25.7 %		27.3 %	

TABLE IX. - HAIRINESS

Description	Percentage Hairiness *					
	Lot A			Lot B		
	Sample 1	Sample 2	Mean	Sample 1	Sample 2	Mean
Card Sliver	2.2	2.1	2.2	4.9	4.6	4.8
Top	2.4	2.7	2.6	5.2	5.3	5.3
Noil	2.5	2.5	2.5	4.6	4.9	4.8

* Equivalent percentage of coarse, hairy fibre having the same proportion by volume of medulla.

Results of tests on yarns from bobbins taken to represent the different spins (see Tables XI and XII) show no significant difference in count between the A and B yarns, though the latter yarns show greater variability in twist and strength.

Twenty strength tests were made on each of four bobbins for each of the single yarns, and forty twist tests were made on each of four bobbins for the weaving varns and on each of two bobbins for the other single yarns. The twist determinations were made on successive 1-in lengths for the single yarns, and successive 5-in lengths for the two-fold yarns, while the strength tests were conducted on 18-in lengths, one yard being allowed after each test length.

TABLE X. - SPINNING TRIALS

Yarn	Time Period (min)	Lot A	Lot B
		Ends down per spindle hour	Ends down per spindle hour
36s weaving; cap frame No. 1; 46 spindles each side; spindle speed, 6880 R.P.M.	130 140 130 130	0.13 0.18 0.20 0.17	0.18 0.33 0.31 0.25
	530	0.17	0.27
Spinning Limit Tests 48s from 3¼ dram roving; 21 spindles each side	30 24 32 18	0.77 1.43 0.71 0.80	2.77 1.77 1.51 2.72
	104	0.93	2.19
52s from 2 dram roving; cap frame No. 8; same 23 spindles for A and B; spindle speed, 6100 R.P.M.; R.H., 54-72%.	30 30 30 30	1.04 1.23 0.86 0.96	1.90 2.27 2.53 2.27
	120	1.02	2.24
52s from 2 dram roving; cap frame No. 1; after reversing sides for A and B; 21 spindles per side; Spindle speed, 6880 R.P.M.; R.H., 85-54%.	30 30 30 30 30	1.34 1.63 0.94 2.00 1.63	3.03 2.77 2.86 3.52 3.03
	150	1.51	3.44
56s from 2 dram roving; cap frame No. 8; 23 spindles per side; Spindle speed, 6080 R.P.M., R.H., 80-70%.	15 15 15 15 15	2.42 1.56 1.56 2.61 2.42	could not be spun.
	75	2.11	

In comparing the strength of the yarns a small difference in favour of Lot B is evident. As shown by the coefficient of variation of the twist results, the yarns differed in levelness, those of Lot B being the less level. In the case of the 52s spinning limit yarn at least, the difference in levelness may have been due to the difference in levelness of the roving.

Knitted Fabric

The hosiery yarns were knitted into a tubular length of plain fabric (weighing 25 lb in the grey state) on a Mellor Bromley Type SAA machine, cylinder 20-in diameter, 16 needles per in and with 12 feeds. The yarns ran well, no run-offs occurring with the Lot A though 2 run-offs occurred with the Lot B. The finished fabric was found to have 28.2 courses per in, which is tighter than is normally knitted. Both lots were each knitted with the same tension.

TABLE XI. - WEAVING YARN TEST RESULTS

Character tested	Singles (1/36s)		Twofold (2/36s)	
	Lot A	Lot B	Lot A	Lot B
Count, mean	35.7	35.6	17.2	17.2
Strength, mean (oz)	3.46	3.65	9.64	9.87
" S.E.	0.06	0.07	0.22	0.20
" C. of V. (%)	15.9	17.2	14.8	12.8
Elongation at max. load, mean (per cent.)	6.10	6.63	15.6	14.0
Mean strength count product	124	130	166	170
Mean Hank Strength (lb)	28.6	28.5	-	-
Twist, mean (T.P.I.):-				
"Z" twist in singles	16.5	16.5	-	-
"S" twist in twofold	-	-	17.9	18.3
S.E.	0.32	0.38	0.22	0.23
C. of V. (%)	24.8	28.9	10.9	10.5

TABLE XII. - HOSIERY YARNS & 1/52s SPINNING LIMIT YARNS - TEST RESULTS

Character tested	Hosiery 1/18s		1/52s Spinning Limit	
	Lot A	Lot B	Lot A	Lot B
Count, mean	17.8	17.8	51.9	51.3
Strength, mean (oz)	6.88	7.29	1.97	2.09
S.E.	0.19	0.16	0.12	0.09
C. of V. (%)	12.2	9.6	38.1	26.6
Elongation at max. load (%)	7.4	7.7	7.1	6.7
Mean Strength count product	122.4	129.7	102	107
Twist, mean "Z" (T.P.I.)	8.23	8.13	22.9	22.5
S.E.	0.18	0.28	0.75	1.22
C. of V. (%)	13.5	21.2	20.8	34.4

TABLE XIII. - SHRINKAGE ON WASHING KNITTED FABRIC

Shrinkage in 2½-hr test	Lot A	Lot B
Length, mean (%)	9.2	9.9
S.E.	0.34	0.47
Width, mean (%)	-4.9	-4.1
S.E.	0.22	0.30
Area, mean (%)	4.7	6.2
	0.45	0.58

The results of shrinkage-on-washing tests (B.S.I. Tentative Textile Standard No. 1a, 1942), carried out on 12 patterns from each of the A and B fabrics, are given in Table XIII. The B fabric shows a small but significantly greater shrinkage than the A fabric, though both show an unusually high shrinkage resistance, which is probably due to the exceptionally long staple of the wool used in this processing trial. Yarns composed of long fibres would be expected to felt more slowly than yarns of shorter ones due to the movement of the long fibres being restricted at more points.

No differences of commercial importance were apparent between the A and B fabrics.

Weaving and the Finished Cloth

In weaving the cloths, more breaks occurred in the warp of B, but the significance of these breakages was obscured by the fact that many of the breakages in both lots were due to slippage of knots.

The finished cloths, whether dyed or undyed, did not reveal any differences between Lots A and B according to the many people who judged them. The presence of medullated fibres in the B fabric did not produce any skittery effects in the dyed cloth, nor were any differences in shade between medullated and non-medullated fibres detected under the microscope. A count under the projection microscope of the number of fibres showing medullation gave Lot A, 4 per cent and Lot B, 11 per cent.

Strength and elongation measurements on the undyed and finished cloths were made on test pieces 6§ in wide (frayed width) on a horizontal-type Goodbrand machine (566 lb capacity) with 7 in between the jaws, and a pulling-speed of 18 in/min. For each piece of cloth, six warpwise samples from positions distributed across the full width of the fabric and eight weftwise samples covering four different sets of weft threads were tested. The mean results for each set of measurements are shown in Table XIV.

TABLE XIV. - CLOTH TESTS; STRENGTH AND ELONGATION*

Material	Warpwise				Weftwise			
	Lot A		Lot B		Lot A		Lot B	
	Strength (lb)	Length* (in)	Strength (lb)	Length* (in)	Strength (lb)	Length* (in)	Strength (lb)	Length* (in)
Undyed (Scoured only)	344	10.8	339	11.1	363	10.8	368	10.7
Dyeing 1	301	10.2	301	10.0	328	9.5	325	9.5
Dyeing 2	305	10.4	301	10.0	332	9.8	329	9.9
Dyeing 3	305	10.2	308	10.0	334	9.8	348	10.7
Dyeing 4	355	10.8	331	10.7	361	10.3	355	10.3

* The results given are those recorded from the machine and are the total extended lengths of the test-pieces at rupture.

The strength tests as a whole, showed no significant difference between A and B. Similarly, measurements of the elongation at break of the test patterns showed no significant difference between A and B. The usual changes in cloth strength, as affected by the method of dyeing and the final reaction of the cloth, were evident in both A and B.

Conclusions

Corriedale hogget wool of 56s to 58s quality, containing medullation equivalent to 6.3 per cent of coarse, hairy fibre, was found to have slightly less satisfactory spinning properties at 1/36s worsted count and higher, than a batch of wool containing 2.9 per cent medullation; the two wools, however, matched in every other characteristic. No differences in performance were detected up to spinning. When spun to 1/18s and 1/36s worsted count the more hairy wool produced a slightly more uneven yarn, as shown by its larger coefficient of variation of twist. This observation of the superior spinning property of the less hairy wool finds support in the corresponding observations of Townend and McMahon (*loc. cit.*) on Romney hogget wool.

Apart from the small effects on the spinning properties, the variation in medullation between the two wools caused no appreciable differences in the appearance and handle of either woven or knitted fabrics, whether in the undyed state or after dyeing navy blue, blue, red or green and finishing by the usual processes.

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SPRAY TREATMENTS WITH LEAD ARSENATE FOR CONTROL OF CODLING MOTH (*Cydia pomonella* L.) ON APPLE TREES

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Summary

The investigation showed that under conditions of heavy infestation, as occurs each year in some commercial orchards, lead arsenate at 1½ lb to 100 gal applied at normal intervals of 14 to 18 days from petal-fall failed to give adequate control of codling moth. Increase in the dosage rate to 4½ lb to 100 gal showed little improvement in control and increased fruit and foliage injury, but reduction in the intervals between spraying to eight days reduced codling moth damage.

Where lead arsenate sprays are efficiently applied overwintering populations are reduced, and it is shown that under these conditions the normal lead arsenate programme gives adequate control.

Trials in which the petal-fall spray of lead arsenate is omitted show only a slight increase in codling moth damage as compared with normal treatments commencing at petal-fall.

Introduction

For many years acid lead arsenate has been the principal insecticide used in New Zealand for control of codling moth. Treatments commence at petal-fall with dosages of 1½ to 2 lb to 100 gal water and are repeated at 14 to 18 day intervals throughout the growing season. Six to ten sprays are applied, the number depending on the apple variety sprayed and on local severity of infestation. In districts favourable to codling-moth these treatments have not always been satisfactory. Losses from larvae entering fruit have been heavy, and fruit has been degraded in quality because of numerous codling "stings." Growers attribute failure to increased resistance of the larvæ to poisoning by lead arsenate. In consequence there has been a trend towards increased dosages and earlier and more frequent applications of lead arsenate. These practices have increased the risk of spray injury (Taylor, 1950) and in most instances have failed to give any marked improvement in control. At the same time, difficulties have arisen where, from early applications of lead arsenate, residues toxic to bees have been left on the blossoms. Bee mortalities have become so high that legislation prohibiting the use of lead arsenate on trees in bloom has been enacted.

In orchards where lead arsenate sprays have failed to give adequate control it is claimed that most of the damage is caused by codling "stings." Where corrugated paper or sacking bands are placed around trees in such orchards they are often found to carry in excess of 100 larvæ per band, indicating a heavy overwintering population. It is this source of infestation which provides the continued and often increasing difficulty in codling moth control. However, there are orchards, often adjacent to those where control is inefficient, in which normal spray programmes prove adequate. In comparing such results the efficiency of spray coverage is of major importance (Taylor, 1939). It is found in practice that efficient control is most frequently associated with orchards where trees are sprayed individually, and that severe infestation is often associated with spraying by outfits of the "crawler" type where efficient spray coverage is difficult to attain.

There are thus two sets of conditions under which lead arsenate is used in orchard practice. In the first, overwintering population of larvæ are reduced to a minimum, whereas in the second, overwintering populations are large and severe reinfestation results each year. The present paper deals with the use of lead arsenate under these two sets of conditions.

Experimental Methods

Most trials were carried out at the experimental orchard, Havelock North, but in some instances results obtained from commercial orchards are reported. The Sturmer variety was selected for spraying because it is a major variety and is highly susceptible to attack by codling moth. All treatments were applied at a nozzle pressure of approximately 300 lb per square inch using a 6-ft rod with twin nozzles delivering approximately 3.5 gal per minute.

Certified brands of lead arsenate were used in which 90 per cent of particles by weight were less than 10 μ diameter and soluble arsenic was less than 0.2 per cent arsenic pentoxide. All treatments were combined with colloidal sulphur paste (40 per cent sulphur), 2 lb, plus hydrated lime 3 lb to 100 gal. Lime sulphur (15 per cent polysulphides), $\frac{1}{2}$ gal to 100 gal, was included in some treatments.

Records were taken at harvest time by sorting fruit into two categories, viz. (1) internal codling grub, i.e. damage by larvæ within the fruit tissues, and (2) codling stings, i.e. fruit which showed only superficial damage from attempted entry by larvæ.

Treatments were applied to plots of two or more trees and were randomized in replicated blocks. Results were examined statistically, and, where necessary, differences for significance are based on equivalent angle transformations of percentage infection.

Results

Seasonal Control at Havelock North Experimental Orchard

Records of codling moth damage over eleven years from 1935-36 to 1946-47 seasons are given in Table 1. All records were taken in the same block but not from the same trees each year because the location of sprayed and check trees were varied from one season to another.

Atkinson and Taylor (1941) pointed out that when first taken over in the 1935-36 season this orchard was very heavily infested with codling moth. Spray treatments in that year gave only partial control. No records were taken in the first year of 1936-37, but in the next season improved control was secured. During the next three seasons all trees were sprayed with lead arsenate except three check trees in the 1940-41 season, and although no records were taken observations showed that codling damage was progressively reduced to a level where it was of no commercial significance. In the 1941-42 season severe infestation developed on check trees which were again left unsprayed, but on sprayed trees good commercial control was maintained. Unsprayed trees were left in this block in each of the following three seasons and consequently sources of heavy infestation were again established with the result that lead arsenate failed to maintain commercial control. In the 1945-46 season, only a few trees were sprayed with lead arsenate, DDT being used on the remainder, and no trees were left unsprayed. Control by lead arsenate was good, probably because of the eradication of sources of infestation by DDT. In the following season DDT was again used

on many trees. Lead arsenate gave good control of codling moth, and although check trees became infested the degree of attack was less than normally occurs. Thus in the last two seasons lead arsenate gave good control under conditions of reduced infestation following use of DDT on most of the trees.

Dosage Rate of Lead Arsenate

In the 1943-44 season Sturmer trees on the experimental orchard were sprayed with lead arsenate at three dosage rates as shown in Table II.

TABLE I. RECORDS OF CODLING MOTH INFESTATION ON STURMER TREES SPRAYED WITH LEAD ARSENATE (LA) AT EXPERIMENTAL ORCHARD, HAVELOCK NORTH.

Season	Percentage of fruit infested by			
	Sting		Internal Grub	
	Sprayed with LA *	Check +	Sprayed with LA *	Check +
1935/36	62.7	7.8	20.3	90.6
1936;37	-	-	-	-
1937/38	39.2	6.1	10.4	85.6
1938/39 to)	No records	-	-	-
1940/41)		6.8	-	74.0
1941/42	11.5	5.0	2.0	90.0
1942/43	22.4	-	5.3	81.9
1943/44	38.0	4.6	12.2	90.8
1944/45	23.7	8.2	3.6	82.3
1945/46	9.6	-	1.6	-
1946/47	12.9	21.8	0.4	78.2

* Acid Lead Arsenate, 1½ lb to 100 gal.

\+ No insecticide applied throughout the season.

TABLE II. EFFECT OF VARIABLE DOSAGE RATES OF LEAD ARSENATE ON CODLING MOTH CONTROL (STURMER VARIETY, HAVELOCK NORTH EXPERIMENTAL ORCHARD).

Quantity of Lead Arsenate per 100 gal * (lb)	Percentage of fruit infested by		
	Stings	Internal Grub	Total
1½	38.0	12.2	50.2
3	41.4	10.2	51.6
4½	43.1	7.6	50.7
Check+,(no insecticide).	4.6	90.7	95.3
Difference for significance at 5%	3.6	5.8	-

* Eight sprays applied from 27 Oct. to 19 Mar.

\+ Infestation percentages from check were not included in statistical analysis.

Trees were subject to severe attack by codling moth from a heavy over-wintering population from the previous season, as shown by the degree of injury on check trees. A progressive reduction in the percentage of grub-infested fruits occurred with increase in the dosage rate of lead arsenate but differences are not significant. The number of fruits damaged by codling stings increased with the higher dosage,

there being a significant increase with lead arsenate 4½ lb to 100 gal compared with the lowest dosage rate of 1½ lb to 100 gal. This apparent anomaly is explained by the fact that total infestation is measured by the sum of established infestations plus stings. When larvæ succeed in entering the fruit, damage is recorded as internal grub and percentage of stings is correspondingly reduced.

Increase in spray injury on fruit and foliage was observed with increased dosage rate of lead arsenate.

TABLE III. FREQUENT APPLICATIONS OF LEAD ARSENATE 1½ LB TO 100 GAL COMPARED WITH A NORMAL SPRAY PROGRAMME. (STURMER VARIETY, HAVELOCK NORTH EXPERIMENTAL ORCHARD)

Number of sprays and approximate intervals	Percentage of fruit infested	
	Stings	Internal Grub
1. 10 sprays: 17-day intervals 21 Oct. to 16 Mar.	23.7	3.6
2. 13 sprays: 17-day intervals 21 Oct. to 4 Feb. and 7-day intervals to 23 Mar.	23.1	5.3
3. 17 sprays: 8-day intervals 21 Oct. to 30 Jan. and 15-day intervals to 16 Mar.	11.2	1.6
4. * Check, no insecticide	8.2	82.3
Difference for significance at 5%	9.3	2.3

* Infestation percentages from check were not included in statistical analysis.

TABLE IV. CODLING MOTH CONTROL FROM SPRAY PROGRAMMES COMMENCING IN LATE BLOSSOM PERIOD COMPARED WITH THOSE COMMENCING AFTER COMPLETE PETAL-FALL

Orchard and season	Variety of apple	Spray programme commencing at petal-fall			Spray programme commencing after complete petal-fall		
		Date	Percentage of fruit infested		Date	Percentage of fruit infested	
			Sting	Grub		Sting	Grub
1946/47 season							
Orchard 1	Sturmer	25 Oct.	21.2	1.6	2 Nov.	20.0	1.0
" 2*	Sturmer	26 Oct.	3.5	0.3	31 Oct.	5.9	0.0
" 2	Granny Smith	26 Oct.	2.1	0.1	2 Nov.	1.7	0.2
" 2	Jonathan	26 Oct.	0.1	0.2	2 Nov.	0.8	0.6
" 3	Sturmer	22 Oct.	9.7	1.0	29 Oct.	13.6	1.0
1947/48 season							
Orchard 1	Sturmer	22 Oct.	5.0	2.3	30 Oct.	5.6	3.4
" 4	Sturmer	23 Oct.	5.2	1.7	3 Nov.	6.1	2.3
Average			7.2	1.2		8.0	1.4

ANALYSIS OF AVERAGE INFESTATION OF ALL ORCHARDS

Treatment	Stings		Internal grub (%)
	(%)	Equiv. angle	
Programme commencing late blossom	7.2	14.0	1.2
Programme commencing after petal-fall	8.0	15.2	1.4
Difference for significance at 5%	-	1.1	0.5

* Because of missing plots this treatment was not included in the general average.

Intervals between Lead Arsenate Sprays

Results from spraying at frequent intervals during the early and late summer of the 1944-45 season are given in Table III. The experiment was carried out at the experimental orchard under conditions of severe codling moth infestation.

Significant improvement in codling moth control was secured following the application of 17 sprays in Treatment 3 as compared with the normal spray programme of Treatment 1. In Treatment 2 the use of close ratio sprays in the late summer failed to improve control.

Petal-fall Sprays of Lead Arsenate

In the course of experiments on codling moth control, treatments have been compared in several trials in various orchards in which normal lead arsenate programmes commencing at petal-fall have been compared with others in which the petal-fall spray was omitted. The period between commencement dates of the two programmes varied from 6 to 11 days. Results are given in Table IV.

Results show that where the first lead arsenate spray was applied after complete petal-fall a significant increase occurred in the number of apples damaged by stings but not in the percentage of fruit showing internal grub damage. However, the increase of 0.8 per cent of fruit showing stings was too small to be of commercial importance.

DISCUSSION

Results over a series of years at the experimental orchard, Havelock North (Table I) show that when overwintering populations of codling moth are heavy the normal spray programme of lead arsenate does not give adequate control. Attempts to improve control under such conditions by applying heavier and more frequent dosages of lead arsenate are only partially effective in the season of spraying. Such practices are costly and liable to cause increased tree injury, and would be justified only as a means of reducing populations of overwintering larvæ to a level where control with normal programmes could be more readily secured in later years.

Although evidence from the experimental orchard shows the deficiency of a normal lead arsenate programme under conditions of severe infestation, the evidence also shows that in the absence of check trees as a source of reinfestation efficient control can be secured. This fact is demonstrated by results obtained in Orchard 1, Table IV where a normal programme, though failing in the first year, gave efficient control in the following season. The efficacy of the normal lead arsenate spray programme is also shown in results from Orchard 2, Table IV.

Comparison of normal spray treatments with those in which the petal-fall spray is omitted indicates a slight improvement in control by the petal-fall lead arsenate spray. At the petal-fall period, however, numerous blossoms still remain, and consequently trees sprayed at this time may result in severe mortalities amongst bees. Since the improvement in codling moth control is of little commercial importance the use of lead arsenate at the petal-fall period is not justified.

ACKNOWLEDGMENT

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YIELD AND COMPOSITION OF MILK OF NEW ZEALAND BERKSHIRE SOWS

By D. M. Smith, Ruakura Animal Research Station, Animal Research Division, Department of Agriculture, Hamilton

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Summary

1. The results are presented of an investigation on the yield and composition of sows' milk, using five Berkshire, over their first three lactations.

2. As a preliminary, observations were made on the interval between sucklings. The mean interval was found to vary between 60 minutes during the first week of lactation to 70 minutes during the eighth week.

3. The mean daily yield per sow was 14.4 lb.

4. The peak yield was reached in the fifth week of lactation.

5. The average composition of milk in the third lactation was: Fat, 7.7 per cent; Protein, 6.2 per cent; Lactose, 5.0 per cent.

6. The differences between the results presented in this paper and those previously published, emphasise the need for further investigations on sow nutrition and milk production.

Introduction

Various research workers have concerned themselves with the milk yield of sows, recognising its importance as a factor in the production of pig-meat. Others again have obtained sufficient milk by subterfuge or design to establish the average composition and the change in composition of the milk over the lactation period. The results, however, relate only to certain strains and to certain isolated systems of management and feeding. In consequence, it is not possible, by comparing the yields and the conditions under which they were obtained, to arrive at any ideal rationing system for the lactating sow. The author considers that, while the establishment of a typical lactation curve is a contribution to our knowledge on the effect of a specific set of conditions, its importance in terms of sow nutrition can only be derived from a study of the effects of varying nutrition upon the shape and quantitative value of the curve.

Investigations conducted on the composition of sows' milk have yielded valuable data, and have established certain trends, but this work has not been conducted in association with yield studies. There is also a lack of information upon the effects of nutrition on composition.

It is realised that the rations at present advocated do provide for what is considered satisfactory litter growth. However, these growths are only satisfactory in relation to the general average within particular areas, and do not provide a measure of the effect of any one of the factors that probably influence milk production, such as the condition of the sow at farrowing, the level of feeding at successive stages in the lactation, or the type of ration used. In addition, these factors are complicated by the intake of supplementary food by the litter after the fourth week. A comparison of accepted weaning-weight standards in different countries and under widely differing conditions of feeding and management, indicates the possible scope for investigation in the field of sow nutrition and milk yield. Such a comparison also leads one to suspect that the established principles of sow feeding have been evolved empirically from local production standards, and are to that extent arbitrary.

An example may be quoted of two standards set by two bodies concerned with litter recording. The committee of the East Anglican Pig Recording Scheme set as a satisfactory level of weaner production a litter of eight pigs averaging 28 lb (Duckham, 1929). The Manawatu-Orua Pig Recording Club set a standard of 300 lb per sow per litter (McMeekan, 1936). As previously suggested, these standards are probably closely related to the general average, and are the expression of feeding, breeding and management practices. The author does not consider that the higher weaning weights obtained in New Zealand—the 300-lb litter is not confined to the Manawatu district—are due to better housing or management than that pertaining in East Anglia, nor can it be claimed that the New Zealand pig stocks are genetically superior to their parent stock in Britain, since no rational breeding scheme aimed at high milk production has been practised in this country. It appears probable that New Zealand sows do produce more milk than sows in England; the magnitude of the difference and the reason for it requires investigation. Further, since the feeding system recommended in New Zealand is a purely arbitrary one, and not necessarily the best, there is no reason to suppose that a 300-lb litter will eventually be classed as satisfactory. It was against this general background that the present work was started, having as its aim the measurement of the milk production of sows, with special reference to the quantity and quality of milk produced under a set of specified conditions. With this as a basis, the nutrition might be varied in such a way as to measure the effects of changes in quantity and quality of foodstuffs at various stages of pregnancy and lactation.

This report deals with the milk production of sows under specific feeding conditions, and will be followed by further reports on the lines indicated above.

Experimental Methods

Five purebred Berkshire sows were used in this investigation. Milk yields were measured over their first, second, and third lactations. The method employed in determining milk yield was as follows:—

(1) Sows and litters were kept under observation for 24 hours once each week, and records made of the number of times each litter suckled its dam, and the time between sucklings.

(2) Upon the day following the suckling observations, the litters were separated from the sow at approximately 4 a.m. If, for example, the average suckling interval determined was one hour, the pigs were allowed to suckle without weighing at 5 a.m., removed until 6 a.m., and again suckled. Each pig was weighed before and after suckling at 7 a.m. This routine was continued until 6 a.m. on the following morning.

(3) This procedure was followed each week. The milk production for the 24 hours, multiplied by seven, was taken as representing the yield of the sow for the week. These values were entered graphically, and the average production for the five sows on a weekly basis from time of farrowing was obtained by interpolation.

(4) After the last weighing in the measurement of yield had been performed at 6 a.m., the litters were allowed to suckle at 7 a.m., and again removed. At 8 a.m. the sows were driven into a race and milked, using pictocin to stimulate normal let-down. In

the earlier stages of the experiment, milking was done by hand, but in the later stages a milking machine constructed for this purpose was used. (Smith, Whittleston and Allen, 1951). The dose used was regulated to produce a yield as near as possible to the average quantity taken by the litter at each suckling over the previous 24 hours.

(5) Rations were fed to sows and litters on the following basis: Each sow was given six units of feed plus one unit for each pig in the litter. (A unit is considered here as a gallon of skim-milk, or 1 lb of meal mixture, consisting in this case of 1 part by weight of 60 per cent protein meatmeal, and 3 parts of barley-meal.) The ration over the eight weeks consisted of 40 per cent milk and 60 per cent meal. The same ration was fed during the three lactations.

(6) Creep rations for the litters were provided at the end of the third week during the first two lactations, and at the end of the fourth week in the third lactation. These consisted of meal as already described, fed dry in one trough, and fresh skim-milk fed in a separate trough. From the beginning of the third week, the litters were kept out of the sty until the sow had finished all the feed in her trough, so that no confusion would exist between sow intake and litter intake.

(7) Weekly weight records were kept from the time of mating prior to the first farrowing until the third litter was weaned.

(8) During gestation, the five sows were run as a group, fed together, and allowed out on pasture daily. Sows and litters had access to pasture for at least one hour per day throughout the whole of the experimental period.

RESULTS

Suckling Observations

Table I lists the observed suckling intervals as an average for the five sows over three seasons.

TABLE I. MEAN INTERVAL BETWEEN SUCKLINGS FOR FIVE SOWS OVER THREE SUCCESSIVE LACTATIONS OF EIGHT WEEKS.

Weeks in Lactation	Interval between Sucklings	
	Average recorded (min)	Used for Experiment (min)
1	60	60
2	59	60
3	62	65
4	63	65
5	64	65
6	71	70
7	70	75
8	72	75

Since the observations continued over 24 hours, it was possible to compare the interval during the day with that at night. The observation period was accordingly divided by including all sucklings between 6 a.m. and 6 p.m. as day sucklings, and those between 6 p.m. and 6 a.m. as night sucklings. The results are shown graphically in Fig. 1.

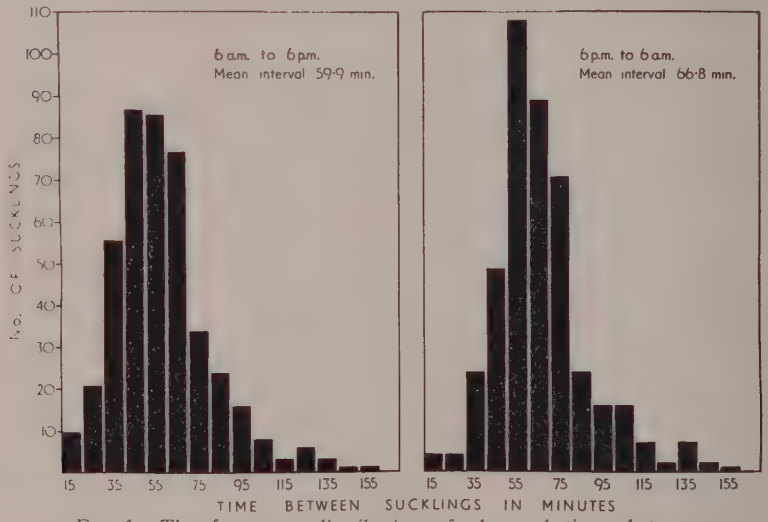

FIG. 1.—The frequency distribution of observed times between sucklings arranged in 10 minute class intervals. (427 day and 437 night observations.)

As a result of these observations, it was not considered that the small difference shown for intervals between sucklings during the day and at night warranted a change in interval over the 24 hours of each experimental period.

Milk Yields

The average lactation curves of the five sows for the three lactations are shown in Fig. 2. No correction has been made for litter size. The curve established by Bonsma (1935) is included here, since it is representative of curves previously produced by other workers in this field.

The average yields for the three lactations are shown in Table II.

TABLE II. MEAN WEEKLY MILK PRODUCTION IN LBS PER SOW OVER THREE LACTATIONS

Lactation	Weeks of Lactation								
	1	2	3	4	5	6	7	8	TOTALS
1st lactation (35 piglets)	44	58	70	82	90	97	89	71	601
2nd lactation (35 piglets)	67	99	112	124	128	124	117	95	866
3rd lactation (41 piglets)	77	114	124	143	149	137	115	98	957
Average of 3 lactations	62.6	90.3	102	116.3	122.3	119.3	107	88	807.8

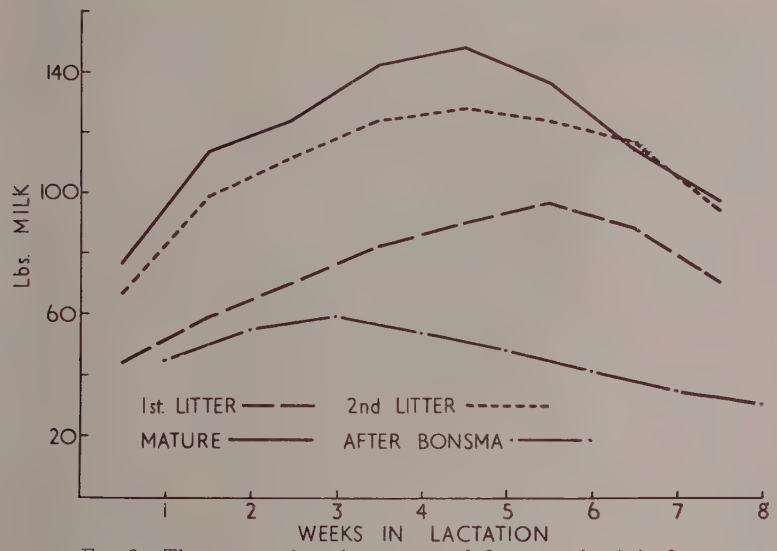

FIG. 2.—The average lactation curves of five sows in their first, second and third lactations.

The essential differences from previously reported work shown in these results are:—

(*a*) The greater total yield;
(*b*) The difference in the shape of the curves, the peak production being reached in the fifth week as against the third week; and
(*c*) The more rapid rise in production after farrowing.

Weight Gains of Litters

Since the level of milk yield should be reflected in the growth of the litter, and is in fact important only in respect to litter gains, the average live-weight increase per litter and per pig is recorded here in Table III.

TABLE III. AVERAGE WEEKLY WEIGHT-GAINS PER LITTER AND PER PIG OVER THREE LACTATIONS

Lactation	Weeks in lactation Weight gain per week								TOTALS
	1 (lb)	2 (lb)	3 (lb)	4 (lb)	5 (lb)	6 (lb)	7 (lb)	8 (lb)	(lb)
(1) Per litter	16.6	19.2	22.9	26.7	26.9	33.2	43.9	41.9	231.3
" pig	2.37	2.74	3.27	3.81	3.84	4.74	6.27	5.98	33.02
(2) Per litter	18.2	24.3	26.4	29.5	33.4	34.1	41.3	45.5	252.7
" pig	2.6	3.47	3.78	4.21	4.78	4.87	5.9	6.5	36.11
(3) Per litter	23.7	30.6	28.5	33.7	36.0	45.4	55.7	59.4	313.0
" pig	2.89	3.73	3.47	4.12	4.39	5.53	6.79	7.24	38.16

The average weight gain per pig is shown graphically in Fig. 3. For comparative purposes the gains of other litters raised under similar conditions are included.

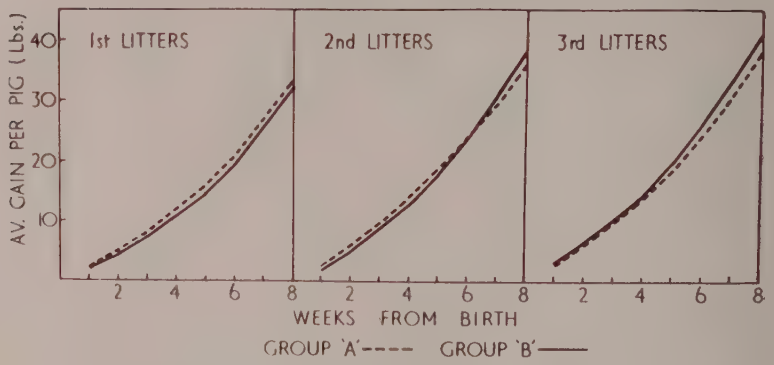

FIG. 3.—The mean cumulative weight gains of the experimental litters (Group A) and the gains made by 13 comparable first, 17 second, and 10 third litters. (Group B.)

Consumption of Food from "Creeps"

As stated earlier, the effect of milk yield should be partly reflected in the growth rate of the litter. While the suckers are entirely dependent upon their dam—in this case until the beginning of the fourth week for the first two lactations, and the fifth week for the third—this relationship should be extremely close; during the period from the fifth to the eighth week, however, the additional food obtained from the creep will tend to mask changes in yield. The average intake of skim-milk and meal for the litters under investigation, together with the records of 32 others, are shown in Table IV.

TABLE IV. AVERAGE WEEKLY INTAKE PER PIG OF MILK AND MEAL FROM THE CREEP OVER THREE LACTATIONS FOR THE LITTERS OF THE 5 MILK-YIELD SOWS AND 32 OTHERS

Lactation	4		5		6		7		8		TOTALS
	Milk (gals)	Meal (lb)	Milk (gals)	Meal (lb)	Milk (gals)	Meal (lb)	Milk (gals)	Meal (lb)	Milk (gals)	Meal (lb)	
1	-	1.2	0.08	2.05	0.68	2.54	1.85	3.77	2.67	4.22	19.06
2	1.0	0.39	1.12	0.93	1.48	0.89	2.04	1.82	3.48	2.58	15.73
3			0.26	0.72	0.85	1.53	1.93	3.28	3.63	4.28	16.48
Average	0.33	0.53	0.49	1.23	1.00	1.65	1.94	2.96	3.26	3.69	17.09
32 others			0.58	1.08	1.68	2.03	3.02	3.18	4.26	4.33	20.16

Table IV shows that the five sows used in this investigation did not differ materially from other sows in the herd in their milk production as measured by litter weight gains, while their litters behaved similarly in the creep.

It is of interest to note that the second litter from the milk-production sows was raised in the summer months, and consumed a greater proportion of its total ration in the form of milk than in the form of meal.

The first and third litters, farrowed in the early spring, showed a preference for meal. The sudden increase in consumption in the sixth, seventh, and eighth weeks, as shown in Table IV, coincides with the fall in yield of sows' milk over this period, shown in Fig. 2. To illustrate

this point further, Fig. 4 was constructed, showing the relationship between average weekly intake of sows' milk per pig and average weekly creep intake per pig over the three lactations.

It can be seen that the consumption of supplementary feed by the litters is largely determined by the yield of the sow. In this respect, Fig. 4 simply supports the impression long held by workers in the field of pig nutrition.

This very close relationship does, however, suggest that control of the shape of the lactation curve by feeding or management could well result in control of the intake of supplementary food by the litter.

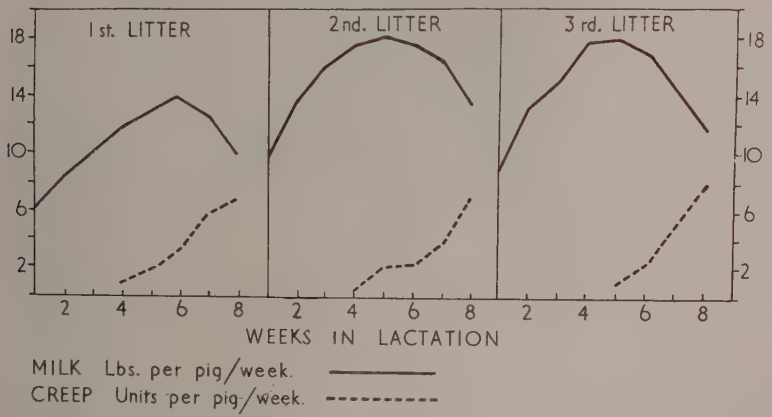

FIG. 4.—The average weekly intake of sows' milk and the average creep intake (in food units) per pig over three lactations.

The Composition of Sows' Milk

It is considered that the study of changes in the composition of milk over the eight weeks of lactation are essential to an understanding of variations in litter growth. It is logical to suggest that variations in nutrition that may in future be applied to sows will influence not only the quantity of milk produced but also its quality. For this reason samples have been taken each week, excluding the first, from the sows used in measuring milk yield. This work was started during the second lactation and continued throughout the third. Samples were analysed for fat, protein, and lactose content.

As will be described in a later paper, some difficulty was encountered in obtaining a truly representative sample when milking by hand; a milking machine was, therefore, built to perform the actual milking. The average percentage content of the milk of the five sows for the three constituents is shown in Fig. 5.

Despite the precautions taken in the drawing of samples, the milk of individual sows showed wide variations in fat test from week to week. It is not known whether such variations are normal, and it is proposed to investigate this point in the course of further work. In the meantime, the average values obtained to this stage are presented here. The lactose and protein values show a much more satisfactory stability.

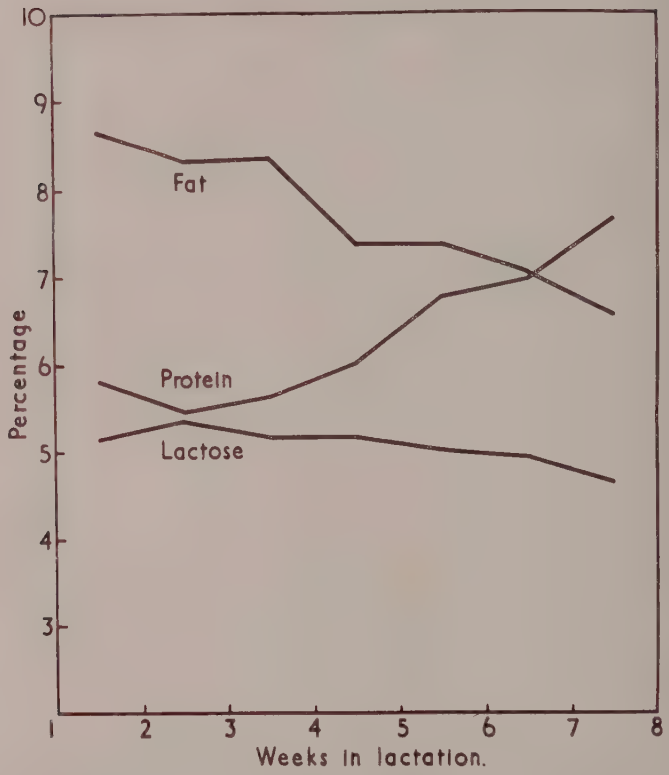

FIG. 5.—The percentage content of fat, protein and lactose (anhydrous) of the milk of the five experimental sows in their third lactation.

DISCUSSION

As has been pointed out in the introduction, the lactation curves of sows have been determined by several research workers in other countries, and the methods used appear to have been fairly standard. However, one phase of the technique does vary considerably, viz. the suckling interval used.

Bonsma (1935) used an interval of between two and three hours, while Henry and Wohl (1897), and later Donald (1937), used a two-hour interval during the day and a three-hour interval at night. The author's observations would indicate that for the sows under investigation both these intervals are unduly long, and that the difference between day and night intervals amounts, on the average, to only about 5-10 minutes.

The Average Interval between Sucklings

Fig. 1 shows that there are occasional periods between sucklings of up to 160 minutes, but these are indeed rare. There is no record in the reports mentioned that any preliminary observations were made to determine suckling intervals. The effects of prolonged intervals between sucklings were examined by Donald (1937), and the conclusion was

that pigs suckling after a long period obtained more milk. The yields obtained, however, showed some variation. Wells *et al.* (1939) state that the natural nursing frequency for their 35 sows observed was approximately one hour, with greater variation in the eighth week of lactation than in the first. They state that sows on a one-hour frequency give approximately one-third more milk than those on a two-hour frequency.

The attitude of the author is that it is extremely difficult to determine the effect of prolonged intervals, and since for one day in seven the sows and litters are subjected to a set of unnatural conditions imposed by the needs of the experiment, the act of suckling itself, and the periods between its performance, should be as nearly normal as possible. To that end, a suckling interval, determined as explained, was used.

The quantity of milk produced by the five Ruakura sows as compared with the yields obtained by other workers is set out in Table V. This table is taken largely from the report by Bonsma.

It is evident that the Ruakura sows have yielded an amount of milk far in excess of any other sows so far recorded. The only suggestion offered in explanation of this fact is that the feeding of skim-milk has resulted in an increased yield. The effect of skim-milk in the ration is to be examined in the near future. However, the fact that the Ruakura sows have yielded such a large amount of milk under a specific set of housing and feeding conditions provides no basic information on sow nutrition, and has little reference to the environmental conditions involved in any similar project carried out elsewhere.

Composition of Sows' Milk

Table VI shows the results of various investigations on the composition of sows' milk.

These results show a reasonable variation, but probably no more than would be expected from different strains of stock kept under different conditions. We are rather more interested in the change in composition during the lactation.

Braude *et al.* (1947) and Bowland *et al.* (1949) are the only investigators who have presented any results on this aspect of production, and unfortunately these data are not related to yield or litter growth. Their results are very similar to those published in this paper.

There is some evidence that the fat content can be influenced by the type of feed. Willett and Maruzama (1946) report that when grain containing 2.8 per cent fat and garbage containing 27.1 per cent fat were fed to sows the following results were obtained:

FEED.	FAT TEST. %
Grain alone	6.1
Grain garbage	7.8
Garbage	9.6

Bowland *et al.* (1949) also record a difference in the fat content of the milk of two groups of sows, one kept on dry-lot and one on pasture.

It would appear, therefore, that the fat content of pigs' milk can be influenced by the type of ration fed, and this phase of production should be explored further. It is of importance to discover the piglet response to an increase in the fat percentage of the dam's milk.

TABLE V. COMPARATIVE DATA ON MILK YIELD FROM NINE INVESTIGATIONS.

AUTHORITY	Breed	No. of Lactations	Average Litter Size	Average Daily Production per sow (lb)	Average Total Production per sow (lb)
Carlisle (1903)	Berkshire	4	7.7	6.31	354.4
"	Poland China	4	7.5	4.86	372.2
"	Razorback	4	6.3	5.17	289.5
Schmidt & Lauprecht (1926)	Landschwein	26	8.3	6.9	388.2
Hampel (1928)	"	22		7.35	411.6
Schneider (1934)	Edelschwein	22	8.3	7.16	401.2
Olofsson & Larsen (1930)	Yorkshire	4	8.5	10.34*	508.5**
Hughes & Hart (1935)	?	2	7.9	6.8	413.2
Bonsma & Oosthuisen (1935)	Large Black	52	6.67	6.55	366.7
Wells, Beeson & Brady (1939)	Poland China & Duroc Jersey	43	-	11.7	655
Present work	Berkshire	15	7.4	14.4	808

* Average for period between 2nd and 8th week.

** Total for 7 weeks.

TABLE VI. COMPARATIVE ANALYSES OF SOWS' MILK FROM SIX INVESTIGATIONS

Authority	Percentage content of constituents			
	Total Solids	Fat	Protein	Lactose
Braude et al. (1947)	19.9	8.2	5.8	4.8
Wells et al (1939)	16.4	5.3	4.9	5.3
Albig	18.8	7.0	-	-
Newlander & Jones	25.1	11.8	-	-
Hughes & Hart	17.8	5.3	6.3	-
Present work		7.7	6.2	5.0

The General Concept of Milk Production in the Sow

Apart from the general lack of information regarding the feeding of sows for milk production, there is also a lack of knowledge as to the most economic level of production. The data presented in this paper on the creep intake of the litter in relation to milk available from the sow, suggest that, if sow yield is too high, the appetite for supplementary food may well be reduced.

On the other hand, it is possible that the level of production up to the fourth week of lactation could determine the weight of the litter at that age, and, therefore, the appetite for supplementary food.

It is possible, therefore, that the aim in the nutrition of the suckling sow will be to control production not only in quantity but also in quality at specific times over the lactation period.

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APPARATUS FOR CONTINUOUS COLLECTION OF URINE FROM THE GRAZING EWE

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(*Received for publication, 22 November 1950*)

INTRODUCTION

Recent work at this Station on reproduction in the ewe has involved measurement of the level of oestrogen excretion in urine. Oestrogen assays require the chemical extraction of relatively large volumes of urine, while any attempt to measure quantitively the oestrogen excretion of ewes necessitates continuous collection over at least a 24-hour period if a representative sample of urine is to be obtained. For many reasons it is also desirable that such collections should be made under normal grazing conditions.

These three essential prerequisites—large volume, continuous sampling, and collection under natural conditions—have necessitated development of suitable apparatus. The equipment herein described has been employed successfully at Ruakura over the past two years. It has been found equally suitable for both non-pregnant and pregnant ewes. It has been used with the same ewe for continuous periods of up to seven days at short intervals extending over several months. No adverse affects upon the ewe have been observed under such conditions.

FIG. 1.—Complete apparatus in use.

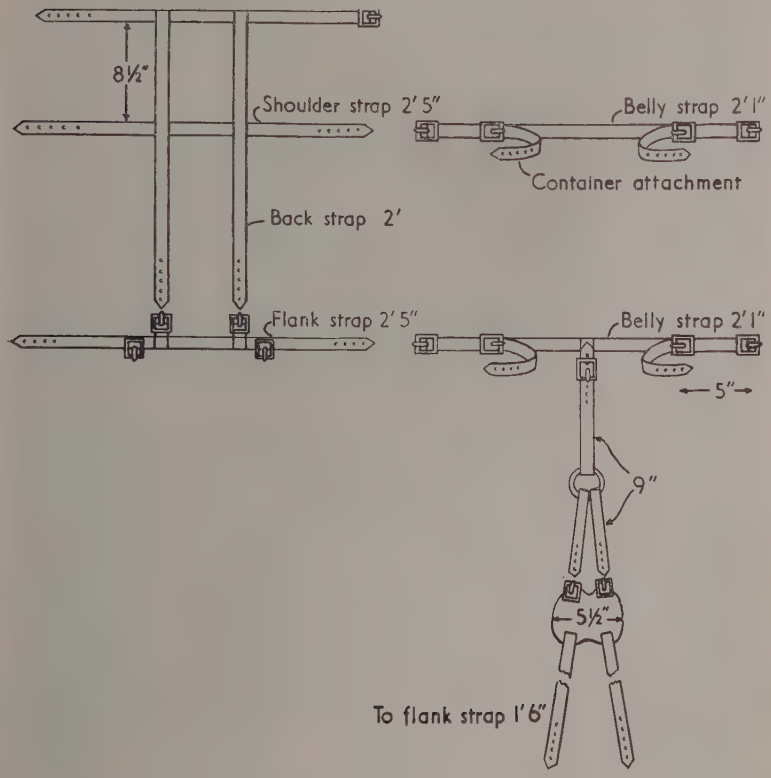

FIG. 2.—Details and dimensions of harness.

DESCRIPTION OF APPARATUS

The equipment is quite readily made, given access to any reasonable workshop facilities. It consists of Harness, Catheter and Container.

Harness

This consists of three adjustable leather straps passing respectively round the neck, behind the shoulders, and round the flank of the sheep. The straps are connected by two further straps of leather passing along each side of the body (Fig. 1). Both side straps are adjustable between shoulder and flank straps. The dimensions shown in Fig. 2 provide a harness that will fit a pregnant or dry ewe of from 100 to 160 lb body weight.

Catheter

To ensure that all urine is collected, a Jaques rubber catheter is used. With dry ewes being handled for the first time size 10 or 12 is suitable. As ewes become accustomed to the equipment or as pregnancy advances, size 15 is sometimes necessary to prevent leakage round the perimeter of the catheter.

FIG. 4.—Catheter in position.

FIG. 5.—Container connected to catheter plate tube and attachment of plate to flank strap.

At the point of exit from the ewe, the catheter is attached to a duralumin tube of 9 mm internal diameter. This is bent at right angles to the line of exit and welded to a duralumin plate (Fig. 3), to the top of which are rivetted two straps. These allow the plate to be fixed to the flank strap of the harness. The bottom of the plate carries two buckles which connect it with the container by way of a metal ring (Figs. 4 and 5). This arrangement permits the catheter to be held firmly in position. After experience with several alternative materials it has been found that duralumin is very suitable because of its light weight and strength.

Container

The container is made of commercial perspex, of 3/16 in thickness moulded in a wooden mould and blown to the shape illustrated (Fig. 3). Perspex has been found very suitable for the purpose. It is light, chemically inert, and sufficiently transparent to enable the efficiency of collection to be observed. A concave upper surface permits the container to fit snugly against the body of the ewe. A similar shape for the bottom of the container facilitates free draining. The container is approximately 25 cm long by 27 cm wide by 5½ cm deep. It holds approximately 3-3½ l which permits an average 24-hr collection. A rubber lead connects the container with the catheter plate tube. To prevent back flow of urine a perforated rubber condom provides a satisfactory valve. This is fitted as shown in Fig. 6. The body of the container is provided with an air escape valve (Fig. 6), which is located in one corner of the top surface so as to prevent all losses through normal movement of urine resulting from movement of the sheep. Minor losses may occur if the ewe lies well over on the same side as that on which the valve is located. Observations indicate that this occurs infrequently. The body of the container rests in a stainless steel basket formed by six metal strips 1 in wide, to which the shoulder and flank straps can be attached as shown in Fig. 1. To permit easy recovery of urine without removal of the equipment the bottom of the container is fitted with a threaded bakelite plug.

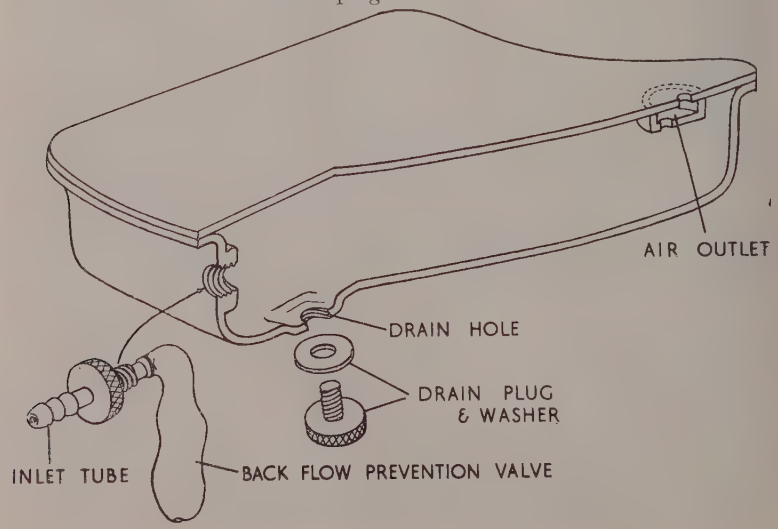

FIG. 6.—Details of construction of container.

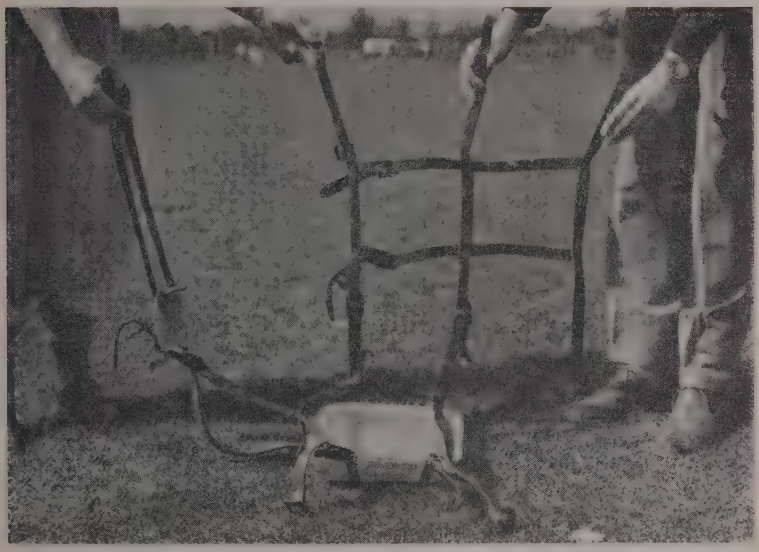

FIG. 7.—Apparatus assembled ready for attachment to ewe.

METHOD OF USE

The complete equipment with the exception of the rubber catheter is assembled prior to attachment to the ewe (Fig. 7). In this condition it is then readily fitted to the ewe. A clean catheter, lubricated with obstetrical cream, is then connected with the catheter plate tube and inserted into the urethra. The plate straps are then fixed to the flank strap over the back.

To obtain a complete 24-hr collection, the apparatus is usually attached to the ewe in the morning. Urine voided during the day is recovered that evening, the night sample being collected the following morning. While a full 24-hr period can be handled by the container as designed, a few individual ewes on high moisture content pasture may yield more than 3½ l of urine per day. Further, if losses through the air valve are to be kept to a minimum, twice-a-day collection is to be preferred.

An occasional animal is encountered which will tend to strain when the apparatus is in place, resulting in small quantities of urine escaping round the side of the catheter. No satisfactory method has yet been devised which will overcome this difficulty.

MAGNESIUM DEFICIENCY IN GLASSHOUSE TOMATOES

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(*Received for publication, 9 October 1950*)

Summary

A case of mottled yellow-leaf symptoms in glasshouse tomatoes has been shown to be due to magnesium deficiency. Effective control has been obtained by spraying with 2 per cent magnesium sulphate.

Laminae of mid-stem leaves appear to be best for diagnosis of magnesium deficiency. Tissue test magnesium levels below about 200 p.p.m., determined on 2 per cent acetic acid extracts of the crushed laminar material, or total magnesium levels below 0.4 per cent Mg in the dry matter of whole leaves, are associated with chlorotic symptoms.

Introduction

In 1948 attention was drawn to the occurrence of severe mottled yellow-leaf symptoms in crops of Potentate tomatoes in glass-houses at Hamilton. The following characteristic symptoms were noted in the 1949 season. In the early stage of the disease, the interveinal tissue of the lower leaves developed a distinct chlorosis, somewhat irregularly distributed in patches, sometimes over the lower and middle parts of the leaflets, sometimes towards the tips and margins. As the symptoms developed, the interveinal tissues became very chlorotic (see Fig. 1) and large necrotic reddish-brown areas appeared. These dead areas extended until the whole leaf finally shrivelled.

Early symptoms appeared in some plants after the first truss had set. In most of the plants, symptoms did not appear till after the third or fourth truss had developed.

The houses where the disease was investigated were established twenty years ago and have had a history of such symptoms over the past fifteen years. Prior to 1939, they were semi-heated, since then, fully heated. Over the past six years the normal management procedure followed approximately the methods advocated by Bewley[1]. Soil treatments were as follows:—

Soil in all houses

Sterilization: formalin; *Liming*: 2½ cwt ground limestone per acre per annum, following 1½-2 tons per acre in 1944; *Base fertilizers*: straw 10 tons, bone dust 3½-4 cwt, superphosphate 5 cwt, potassium sulphate 2½ cwt, all per acre per annum.

Early crop tomatoes only: in 10 in. concrete pots, 9 in. deep, with free access through drainage hole to soil below. *Soil in pots*: rotted turf plus base dressings; *lime*: 8 cwt; *fertilizers*: bone dust, 4 cwt; superphosphate, 5 cwt; potassium sulphate, 2½ cwt, all per acre of ground area of houses. Total effective (pot plus soil) base dressings per acre per annum for potted plants: *lime*: 10½ cwt limestone; *fertilizers*: 8 cwt bone dust, 10 cwt superphosphate, 5 cwt potassium sulphate. At end of season soil from pots tipped out *in situ*.

Sidedressings: *Pots 1949*: 14 cwt superphosphate, 4½ cwt each potassium sulphate and ammonium sulphate, 23 cwt dried blood, all per acre.

* Died November 1951.

Fig. 1.—Chlorotic left; healthy right.

Main crops direct in soil: 55 cwt superphosphate, 18 cwt each potassium sulphate and ammonium sulphate, 90 cwt dried blood, all per acre per annum.

[Note: This rate is five times heavier than the grower intended.]

Foliage symptoms, together with preliminary analyses of plant and soil samples taken late in the 1948 season, pointed to the possibility of magnesium deficiency.

Field Experimentation

In the 1949 season the following experimentation was carried out:

1. Substitution of serpentine superphosphate for straight superphosphate in the base dressing (5 cwt per acre);

2. As 1, but in sidedressings as well as base dressings (total application 3 tons per acre);

3. Borax application in base dressing at 20 lb per acre;

4. Zinc sulphate application in base dressing at 10 lb hydrate per acre;

5. Stable manure (mainly bedding straw) in base dressings at 40 tons per acre in place of 10 tons straw per acre;

6. Trials of injection methods using manganese, molybdenum and magnesium.

7. Spraying with 2 per cent hydrated ferrous sulphate;

8. Spraying with 2 per cent hydrated magnesium sulphate;

9. Sidedressing in pots with magnesium sulphate at the same rate as potash side dressings.

RESULTS

Field Experiments

Apart from slight benefit from spraying with iron sulphate, the only treatments which gave worthwhile results were the heavy application of stable manure and the spraying with 2 per cent magnesium sulphate. Roach's injection technique[2], using small cup reservoirs, successfully indicated magnesium as the critical element, but did not remedy the deficiency in the plant as a whole.

Five cwt serpentine superphosphate (containing 5 to 6 per cent Mg) had no apparent effect on the incidence of deficiency symptoms or yields, and even a further 55 cwt serpentine superphosphate in side dressings had little effect.

The zinc and boron treatments were ineffective.

Side dressings of magnesium sulphate were commenced late in the season, and although a total of 300 lb per acre was applied, there was no apparent effect.

The stable manure delayed the onset of deficiency symptoms till after the fourth truss had set, whereas elsewhere in this house the symptoms were acute from the third truss stage.

The spray treatments were commenced when the plants were about 3 ft high and continued at 3-weekly intervals for five sprayings. Spectacular improvement in the colour of the foliage resulted from the application of magnesium sulphate, especially after the second spraying, but some leaf injury was noted in the first two sprayings, due to a combination of unfavourable conditions, namely, coarse spray, no spreader and overcast weather. After the second spraying, when a fine spray was used with a spreader, and the application was made under sunny conditions, subsequent foliage injury was quite negligible.

Plant analyses

Tissue tests—1948 Season: At the later stages when chlorosis was severe in the lower leaves, the youngest growth at the top of all plants remained apparently healthy, with normal green foliage. Main petioles of this "healthy" young green foliage from the top growth and older mid-stem chlorotic leaves were tested in December 1948 with the following results:—

	Purdue Method			2 per cent Acetic Acid Extracts (p.p.m.)				
	NO_3—N	P	K	NO_3—N	P	K	Ca	Mg
"Healthy" top	VH+	M—	VH	570	73	7300	1200	180
Chlorotic mid-stem	VH+	M—	VH	250	52	5000	3700	630

In the above Table "Purdue" refers to the results by the qualitative Purdue method,[3] using the top line of the colour chart for phosphorus and the bottom line of the turbidity chart for potassium. The 2 per cent acetic acid figures were obtained by the Carolus extraction

TABLE I. TISSUE ANALYSIS IN 2 PER CENT ACETIC ACID EXTRACTS OF CHLOROTIC PLANTS IN POTS IN HOUSE I

Nutrient Element	Amounts of elements found in plants tested on									
	15/8/49		6/9/49		29/9/49		13/10/49		8/11/49	
	Petiole (p.p.m)	Leaf (p.p.m.)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)
NO_3 -N	830	150	780	120	760	150	660		550	20
P	143	198	88	161	53	159	74	221	96	241
K	6600	5200	6100	4200	6500	4800	6500	2900		3700
Ca	1100		750	2400	800	2600	1100	3400	1200	4400
Mg	280	230	190	210	110	100	190	90	230	50
							260+ 250*	80+ 30*	330+	130+

\+ From plants which received side-dressings of Epsom salts commencing 6/9/49. By 13/10/49 total 170 lb per acre; by 8/11/49, 250 lb, and final total 300 lb per acre.

* Selected severely chlorotic sample.

Planted out early June; no base fertilisers or limestone in pots; two side dressings of equal parts superphosphate, potassium sulphate and ammonium sulphate (total 1¼ cwt per acre of each) applied in June; normal side dressings commenced in early July; normal base dressings in soil under pots; growth retarded and chlorosis slight till third sampling.

technique[4], and analytical procedures approximately as described by Carolus for nitrogen, phosphorus and potassium (the latter two modified), the Peech and English method[5] for calcium, and a modification of the Long Ashton method[6] for magnesium. The results are recorded as parts per million of the element in fresh tissue and calculated on the assumption (following Carolus) that the volume of extract is 25 ml.

Tissue tests—1949 Season: Foliage samples from two-thirds the way up the plant stem were taken at regular intervals. Results of analysis of the 2 per cent acetic acid extracts of samples from House 1 are quoted in full in Table I. Magnesium figures only are here recorded in Table II for samples from Houses 2 and 5, as the levels of other nutrients, in spite of the heavier side dressings, were similar to those for House 1. Nitrogen, phosphorus and potassium were determined on all samples by the Purdue method[3] also, but are not quoted as they merely confirm the trend of results by the quantitative Carolus method[4]. Analyses were also made of samples taken 18 in. from the top of the plants for comparison with results for leaves from the normal sampling position. The magnesium figures for Houses 2 and 5 are included in Table II. Samples from magnesium-sprayed plants were washed to remove surface contamination.

Total plant nutrients: Ash analyses of whole leaves (petiole plus leaflets) by standard analytical procedures gave the results shown in Table III. All figures are recorded as percentage of the element in the dry matter at 100°c.

Soil Analyses

Results of analysis of soil samples, shown in Table IV, are recorded as milli-equivalents per cent of cations, or mg per cent of available phosphorus by the Truog method[9], while soluble salts are shown as percentages. The soils were leached with neutral normal ammonium acetate and exchangeable cations determined by standard analytical methods. As preliminary water and aqueous alcohol leaching was not used, the figures for exchangeable cations include cations of any water-soluble salts.

Discussion

The visual responses and analytical data point to magnesium deficiency.

Tissue Test Results: Nitrate-nitrogen, potassium and calcium levels are normal. The phosphorus levels are fair, according to Hester's standards quoted by Emmert[7], but relatively low compared with Emmert's own criteria[7, 8]. There is, however, no evidence that the symptoms observed are the result of a shortage of phosphorus. The rather low levels may in part be a result of the low levels of magnesium reducing the ability of the plant to transport or utilise phosphorus[9], but high fixation is undoubtedly the main reason.

In the 1949 season, the petioles of chlorotic upper mid-stem leaves showed levels of magnesium extractable by crushing with 2 per cent acetic acid, ranging from 100 to 510 p.p.m. of fresh tissue, or 800 to 4100 p.p.m. dry weight at 100°c. In petioles of healthy leaves from the same sampling position on magnesium-sprayed plants the values ranged from 280 to 510 p.p.m. of fresh tissue, or 2800 to 4200 p.p.m. dry weight.

TABLE II. MAGNESIUM IN 2 PER CENT ACETIC ACID EXTRACTS OF LEAVES FROM PLANTS SET DIRECT IN SOIL

Sample	Amount of magnesium found in plants tested on													
	15/8/49		6/9/49		29/9/49		13/10/49		8/11/49		1/12/49		15/12/49	
	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)	Petiole (p.p.m)	Leaf (p.p.m)
House 2														
Normal *	120	100	180	190	250	180	190	170	300	150	370	180		
Top *									200	210	230	260		
House 5														
Control														
Normal	100	120	100	130	130	110	130	60	210	50	300	140	510	210
Top											180	250	150	250
Mg Spray +														
Normal									280	450	350	1740	510	910
Top											320	610	120	240

* "Top" represents green foliage 18 in from top of plant for comparison with "normal" samples taken about two-thirds the way up the stem. Planted early July. In House 2, chlorosis distinct from about 29/9/49; in House 5, severe from about 6/9/49.

\+ Spray applications 29/8/49, 21/9/49, 19/10/49, 9/11/49 and 29/11/49. Plants without magnesium showing chlorosis of lower leaves; magnesium sprayed plants non-chlorotic.

These figures are still somewhat low compared with normal levels as recorded by Carolus[1], which average about 900 p.p.m. Mg, and results of Nelson workers[10], which range from 430 to 1080 p.p.m. in petioles of "healthy" (non-chlorotic) tomatoes. Except at the lower extremes of values, there is little difference in the present results between the levels in the petioles from mid-stem healthy and chlorotic leaves.

Both in the 1948 and 1949 late season samples, apparently healthy green foliage from the top of the plants showed lower magnesium levels in the petiole than severely chlorotic foliage from the lower parts of the same plants. Furthermore, there was little difference between the petiole figures for this green top growth on non-chlorotic sprayed and chlorotic control plants.

Good contrasts, however, are seen in the results for the leaf laminae. In this tissue from mid-stem leaves of chlorotic plants, the magnesium levels range from 30 p.p.m. (Table I) to 210 p.p.m. of fresh tissue, or approximately 200 to 1100 p.p.m. dry matter. In healthy magnesium-sprayed plants the range was 450 to 1740 p.p.m. of fresh tissue or 3000 to 10,000 p.p.m. dry matter. The correlation between the incidence of visual symptoms and the sap levels in the mid-stem laminae is good and appears to be better than the indications from a limited number of analyses of comparable samples from terminal leaves. The results are similar to those of Mikkelsen and Toth[11], who found levels of 100 to 400 p.p.m. magnesium in laminae of terminal leaves of chlorotic plants and 300 to 1200 p.p.m. in normal tomato plants, but the present work indicates that mid-stem leaves may be preferable to terminal leaves for diagnostic purposes. The critical level in the laminae of upper mid-stem leaves appears to be about 200 p.p.m.

TABLE III. TOTAL NUTRIENT CONTENTS OF CHLOROTIC LEAVES. (PERCENT DRY MATTER)

Sample	Element	15/8/49	6/9/49	29/9/49	13/10/49	8/11/49		1/12/49
House 1	P	0.42	0.34	0.32	0.30	0.23		
	K	6.07	6.51	8.34	7.93	5.81		
	Na	0.16	0.20					
	Ca	2.44	2.52	3.92	4.66	5.43		
	Mg	0.41*	0.37*	0.34	0.31	0.32		
	Mn	0.007	0.010	0.027	0.038	0.044		
House 2	P	0.32	0.36	0.36	0.31	0.21		0.29
	K	5.70	6.51	7.45	7.36	6.30		5.47
	Na	0.12	0.14					
	Ca	4.01	4.25	4.07	4.68	5.16		6.50
	Mg	0.29*	0.36*	0.37	0.37	0.34		0.50
	Mn	0.004	0.004	0.005	0.002	0.010		0.018
						Control	Mg^+	
House 5	P	0.49	0.42	0.36	0.28	0.17	0.18	0.25
	K	5.54	6.18	7.21	8.04	5.23	4.72	4.58
	Na	0.14	0.14					
	Ca	4.20	3.69	4.17	5.15	5.40	5.94	7.61
	Mg	0.20	0.26	0.29	0.26	0.23	0.78	0.45
	Mn	0.004	0.003	0.003	0.004	0.003	0.007	0.024

* Chlorosis slight. + Magnesium sprayed (non-chlorotic)

TABLE IV. ANALYSIS OF SOIL SAMPLES

Sample	Notes	Depth (in)	pH	B.E.C.* (m.e.%)	T.E.B.+ (m.e.%)	Ca (m.e.%)	Mg (m.e.%)	K (m.e.%)	P_2O_5 ++ (mg.%)	Soluble Salts (%)
House 1										
49/955	Field soil	(0-9)	6.0	27.4	13.2	11.9	1.15	0.3	4.8	0.02
49/1123	Final	Pots	4.9	29.4	5.0	7.7	0.34	0.9	20.6	0.34
House 5										
48/1147	Old soil	0-12	5.7	25.3	21.4	26.9	0.32	4.3	35	
49/956	Old soil + Serpentine	0-6	5.8	28.4	21.9	23.4	0.93	2.4	316	0.4
49/957	super-phosphate	6-12	6.0	26.2	16.1	18.4	0.77	2.4	197	0.2

* Base Exchange Capacity. + Total Exchangeable Bases. ++ Truog[9]

Note: Exchangeable cations include cations of water-soluble salts.

Sample 955: field sample as used for pots in House 1 in 1949.
Sample 1123: representative sample taken from pots at end of season, after receiving side-dressings only (see Foot note Table I).
Sample 1147: from House 5 in 1948 before any magnesium-containing fertilizers had been used.
Samples 956 and 957: from south end House 5, after 5 cwt serpentine superphosphate had been applied as base dressing and 55 cwt as side-dressings.

Ash Analyses: Phosphorus figures (Table III) were similar to, but potash levels higher than those reported by Nicholas[12], [13] for mid-stem leaves. Calcium was lower, especially in the early part of the season, but similar to values found by Carolus[14]. The omission of lime from the pots in House 1 (footnote Table I) probably explains the higher manganese content of the foliage of plants from this house. Magnesium levels are in fair agreement with those found by Nicholas, values below 0.40 per cent Mg being associated with chlorotic symptoms. The figures of 0.45 and 0.50 per cent Mg for late season moribund foliage may justifiably be disregarded. Nicholas has given 0.3 per cent Mg (0.5 per cent MgO) as the critical level.

The very high potassium contents suggest that the heavy applications of potassium salts may have been in part responsible for the severity of the magnesium deficiency. Examples of potassium induced magnesium deficiency in tomatoes have been reported by Cromwell and Hunter[15], Walsh and Clarke[16] and Hunter[17]. In at least one of these examples[15], replaceable magnesium is described as "high". Heavy applications of potash are, however, considered necessary to control "blotchy ripening".[1]

Soil Analyses: The dominant soil type, Horotiu sandy loam, is normally very deficient in phosphate, and has a high fixing power for phosphate and low potassium reserves. Heavy applications of phosphatic fertilisers are necessary on this soil. Results in Table IV indicate the extent of the build-up of potassium, calcium and phosphorus, and depletion of magnesium in House 5 after cropping for upwards of 20 years and using very heavy side dressings over the past several years.

Where 3 tons serpentine superphosphate per acre has been used, the average magnesium test for 0-12 in. has been raised from 0.32 to approximately 0.85 m.e. per cent. This suggests that serpentine superphosphate, if used in place of straight superphosphate, preferably in both base and side dressings, may in time significantly increase the level of available magnesium and reduce the severity of the deficiency or delay its development.

The levels of total soluble salts tend to be high, figures of 0.6 and 0.7 per cent being noted in some samples not referred to in the table. Though tomatoes appear to be somewhat salt-tolerant, there is evidence[18] to suggest that these levels may be dangerously high. Hunter[17] claims that high soluble salts are liable to result in decreased absorption of magnesium. Furthermore, the sulphate ion, which predominates in the anion portion of the soluble salts in this case, has been shown by the same author to accentuate magnesium deficiency. For these reasons a greater use of fertilizers which leave no residue of unusual sulphate or chloride ions may be advisable in glasshouses where the soil is not regularly renewed.

Prince, Zimmerman and Bear[19], and Zimmerman[20], from work on New Jersey soils, conclude that "if exchangeable magnesium constitutes less than 6 per cent of the exchangeable cations in a soil, crops growing on that soil are likely to respond markedly to applications of the element in soluble form." The exchangeable magnesium in the soil used in the pots in House 1 at the commencement of the season was only approximately 4 per cent of the exchange capacity and 1 per cent at the finish. Even in House 5 after application of 3 tons serpentine superphosphate per acre, the exchangeable magnesium in the top six inches is only

approximately 3 per cent of the exchange capacity. The incidence of magnesium deficiency on this soil lends some support to the conclusions of the New Jersey workers.

Conclusion

Tissue test analyses of chlorotic foliage, and quick test analyses of soils from the Auckland district, together with reports of the incidence of similar symptoms in glasshouses in Dunedin, Christchurch and Palmerston North areas, indicate that magnesium deficiency in glasshouse tomatoes may be widespread in New Zealand. In all cases so far investigated in this laboratory, the incidence of chlorosis has been associated with very high soil potash and low or medium magnesium tests.

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SOIL CHANGES ON AN AUCKLAND PROPERTY FOLLOWING INTENSIVE CULTIVATION

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(*Received for publication, 11 April 1951*)

Summary

In 1937, a detailed soil survey was made of an Auckland property, then under pasture; samples were taken for chemical and mechanical analysis. The property was subsequently put under intensive cultivation for fruit and vegetable plots. In 1949, another survey was made, and comparative samples were analysed. Although the property had been well managed by ordinary standards, there has been considerable soil erosion, soil structure has deteriorated, and as much as 50 per cent of organic matter has been lost.

Introduction

A property near Auckland was converted from grassland to orchard and market garden plots in 1937-8. Immediately prior to this Mr. N. H. Taylor of the Soil Survey Division made a detailed soil survey; over two hundred profiles were recorded, a soil map was prepared, and chemical and mechanical analyses were made of the principal soil types. On this basis a fertilizer programme was recommended. The writers surveyed the property in 1949 to examine the soil changes that had occurred, following the new kind of utilization.

1937 Survey

In his 1937 report (not published) Mr. Taylor describes three main groups of soils:

(1) Podzols derived from sedimentary clays;
(2) Brown loams derived from a basalt flow which partly covers the clays;
(3) Meadow soils on an alluvial valley floor.

Seventeen soil types and seven phases were mapped. Of these 24 units, 9 were sampled for chemical and mechanical analysis; 5 pit samples were taken from the hill soils, and 4 composite samples from the meadow soils.

1949 Survey

In 1949, a second survey was made to see what changes had occurred during the 12 years of intensive cultivation. The sites of the recorded profiles were re-examined and each profile compared in detail with that recorded in the same spot 12 years before. This comparison showed that during 12 years the following changes had occurred:—

(1) The development of a "plough soil" horizon and a "plough sole";
(2) Soil erosion by run-off water;
(3) The movement of soil downhill by cultivation and other mechanical disturbances;
(4) An apparent break-down of soil structure;
(5) Improved drainage on the alluvial flats.

(1) *Plough Soil Horizon*

Under grassland in 1937, individual topsoil horizons were noted as shallow as 3 in. and abrupt topsoil-to-subsoil changes occurred between 4 in. and 6 in. In 1949, in apparently uneroded places, mixing by cultivation had completely changed the profile down to 6-8 in. Subsoil mixed with the topsoil had become a uniform "plough soil" horizon to the depth of cultivation, lighter in colour than the original topsoil. This horizon, kept free and aerated by constant cultivation, contrasted with the undisturbed soil immediately below, which had been tightly compacted by the packing action of wheeled implements and by the development of a "plough sole".

(2) *Erosion*

The soils on most of the slopes have eroded, some of them severely. Soil losses of as much as 18 in. at the heads of slopes and accumulations of as much as 36 in. at the bases of slopes were recorded. It was reported that much soil had been washed away through storm-water drains and that many truck loads had been picked up from areas of accumulation and returned to the higher levels. There had been shallow gullying on several parts of the property, but cultivation has obliterated the individual gullies and an overall thinning of topsoil has resulted. Cultivation up and down the slopes may have facilitated this by leaving small channels into which run-off waters concentrated.

(3) *Soil Movement Downhill*

Much of the soil movement was probably caused directly by implements. Rotary hoes revolving at high speed cause considerable displacement of soil particles, and on a slope the displacement is mainly downhill. Sharp turning at headlands throws soil to the side, and in some places a layer of several inches had been removed by this means from relatively flat surfaces. Much of this soil has accumulated under hedges where it is lost to agriculture.

(4) *Break-down of Structure*

A general break-down of topsoil structure seems to have occurred on both the eroded and uneroded parts of the property. "Crumbly silt loams" recorded in 1937, showed only a weak crumb structure in 1949. This weakening of structure may be caused by:—

(a) Physical breaking down of soil aggregates by finely cultivating implements;

(b) Mixing of subsoil with topsoil;

(c) A considerable loss of organic matter, shown by figures for loss on ignition.

(5) *Drainage of Flats*

Since the property was first surveyed, a drainage system, employing both open and tile drains, has been installed to lead away water from several springs which occur at the bases of some of the slopes, and to lower the water-table of the alluvial flats. Material excavated from these drains and spread on the surface has modified the soil profiles on some of the low-lying areas, and there has been some building up by

soil washed from the slopes above and carried in by the truckload to fill hollows. Hence it is difficult to make a direct comparison of the soil profiles to determine the effects of drainage. It does seem, however, from an examination of the few profiles that are apparently undisturbed, that the water-table has been lowered, as some of the soils which were characterised by dominant reduction colours to within 12 in. of the surface now show oxidation down to about 20 in.

Chemical and Mechanical Analyses

Samples of seven soil types were taken from apparently uneroded sites clear of all fillings and accumulation. Chemical and mechanical analyses of these samples are tabulated in Table II together with analyses of samples of the same types collected in 1937. The principal changes shown by the analyses are:—

(1) Organic matter (as shown by loss on ignition) is lower in all the 1949 samples. Losses as great as 56 per cent have occurred (Table II).

(2) Air dry moisture is lower on all 1949 samples (Table II).

(3) Base exchange capacity is lower on all the 1949 samples. (Table II).

These changes observed on all samples indicate that organic matter has been lost from topsoils over the whole property between 1937 and 1949. The increase in "total sand fraction" in 1949 (Table II) must also be attributed to a loss of finer material rather than to an increase of sand as such.

Although organic matter is of less importance in maintaining structure in brown loams than in most other soils, losses such as these would reduce aggregation and facilitate erosion. Under Auckland's climate, the normal rate of oxidation of organic matter is high, and the intensive cultivation carried out on the property would increase this already high rate It may be that the level of carbon found in the 1949 samples is an "equilibrium" level for these soils under intensive cultivation in Auckland, and that no practicable additions of organic matter by extra cover cropping or other means will raise it appreciably.

Increasing the organic matter is, however, an obvious step in any attempt to control the erosion which is taking place, and experiments to determine whether the present carbon content can be raised by any means which are economically possible should form part of any soil conservation plan.

Phosphate levels are satisfactory on all except two soils, viz. Samples 5536 and 5537, which are derived entirely from basalt, and which would probably fix phosphates more readily than the others.

Liming, as shown by the percentage base saturation and pH, has been adequate on all soils except possibly on the brown loam represented by Sample 5336. It seems likely that this latter sample is not typical—a pH of 4.3 and percentage base saturation of 4 are unusual on young basalt soils. The pH values of Samples 5339 and 5340 are approaching a level commonly associated with the onset of trace element deficiencies, and care should be taken to avoid overliming these soils. A pH of 6.7 is not unusual for a basalt soil with percentage base saturation of 97 (Sample 5339) but seems high associated with a percentage base saturation of 65 (Sample 5340).

TABLE I. DESCRIPTION OF SOIL TYPES ANALYSED

Grid Point	1937 Survey	1949 Survey
1	Brown loam on flattish basalt tops Soil Type 1 (Analysis No. 5336)	
	0- 4 in. Free dark grey brown friable loam; 4-15 in. Fairly free chocolate brown friable loam; 15-24 in. Moderately compact dark chocolate granular clay loam to clay; on Compact dark chocolate granular clay loam to clay; soil stony, surface covered with basalt stones up to 3-4 in. in diameter; more reddish brown and more compact with depth from surface.	0- 6 in. Greyish chocolate brown loam mixed by cultivation; 6-18 in. Lighter chocolate clay loam; on Dark chocolate compact clay loam to clay; very few stones on surface.
162	Brown loam on basalt slopes Soil Type 2 (Analysis No. 5337)	
	0- 9 in. Dark grey brown powdery silt loam; 9-18 in. Dark brown compact crumbly clay; 18-30 in. Very compact dark brown crumbly clay, with sago size alumina nodules. on Lighter brown compact clay loam; slightly floury with soft black nodules.	0- 6 in. Greyish dark brown heavy silt loam; 6-14 in. Reddish dark brown clay loam with iron mottle; 14-18 in. Red brown clay; on Lighter red brown clay loam; few stones in profile.
139	Brown loam - basalt top-soils with clay sub-soils on slopes Soil Type 5 (Analysis No. 5338)	
	0- 7 in. Grey brown silt loam; on Light grey brown compact clay loam with slight rust flecking; the flecking is stronger below 24 in.	0- 9 in. Medium grey heavy silt loam to clay loam; 9-24 in. Pale yellowish grey clay loam flecked with iron and manganese; on Yellowish pale grey clay with some mottling.
15	Yellow brown earth on sedimentary clays (Hill type) Soil Type 7 (Analysis No. 5339)	
	0- 6 in. Grey brown clay loam; on Compact rusty brown and grey to white flecked clay.	0- 4 in. Medium grey silt loam; 4-18 in. Yellowish light grey clay loam with much iron and manganese; on Yellowish light grey clay.
119	Gleyed soil on flats derived from basalt wash over clay Soil Type 12 (Analysis No. 5340)	
	0-18 in. Brown crumbly clay loam (fresh basalt wash); on Brown clay (mixture of basalt and sedimentary clay wash).	0- 6 in. Greyish dark brown heavy silt loam; 6-14 in. Bright reddish brown clay loam; 14-24 in. Medium brown clay loam; manganese concretions; on Medium brown clay with rusty iron concretions.
80	Gleyed soil on flats derived from mixture of basalt and clay wash Soil Type 13 (Analysis No. 5341)	
	0-33 in. Brown clay loam (fresh basalt wash); on Grey clay with rather hard 1/4 in crumbs; flecked reddish brown.	0- 8 in. Greyish dark brown heavy silt loam; 8-15 in. Reddish dark brown heavy silt loam; 15-33 in. Brown, light grey clay, plastic with small manganese and soft iron concretions; on Light grey plastic clay.
71	Gleyed soil on flats. Mostly clay wash Soil Type 15 (Analysis No. 5342)	
	0- 3 in. Grey brown peaty loam (sedgy peat composed of layered leaves); 3-13 in. Dark grey brown clay loam, flecked grey and rust; 13-19 in. Grey clay loam to clay strongly flecked rust brown; on Wet grey clay to clay loam lightly flecked rust brown.	0- 5 in. Greyish dark brown heavy silt loam; 5-18 in. Greyish medium brown silty clay loam with much black and orange mottling; 18-30 in. Brown light grey plastic clay with a little black mottling; on Light grey wet plastic clay.

TABLE II. CHEMICAL AND MECHANICAL ANALYSES OF SOIL SAMPLES

Sample No.	Year	Depth (in.)	pH	Available P_2O_5 (%)	Organic C (%)	Total N (%)	C/N	Base Exchange						Loss of B.E.C. (%)	Air Dry Moisture (%)	Loss on Ignition (%)	Total Fraction (%)	Lime Reqmt.	Soil Type	
								Exchange Capacity (m.e.%)	Total Bases (m.e.%)	Base Satn. (%)	Ca (m.e.%)	Mg (m.e.%)	K (m.e.%)							
2015-6*	1937	0-8	5.3	0.006				53.0	7.6	14					10.5	17.4	18.1	9.0	1	Greyish dark brown silt loam from basalt.
5336	1949	0-6	4.3	0.018	4.3	0.42	10	28.0	1.0	4	2.0	0.95	1.25	47	6.1	17.2	22.3	6.0		
2013-4	1937	0-8	5.0	0.008				45.2	8.8	20					10.1	18.1	18.0	7.0	2	Greyish dark brown heavy silt loam from basalt.
5337	1949	0-6	5.6	0.013	3.5	0.33	11	25.3	10.4	41	9.0	2.05	0.75	44	3.8	7.9	22.2	1.6		
2011-2	1937	0-7	5.3	0.011				29.1	7.7	27					6.4	10.6	32.6	3.5	5	Medium grey heavy silt loam to clay loam from basalt, with sedimentary clay subsoil.
5338	1949	0-6	6.1	0.036	2.7	0.23	12	16.8	10.0	60	8.4	1.55	0.80	42	5.8	7.3	35.0	-		
2007-8	1937	0-6	5.3	0.003				20.9	6.3	32					4.1	10.8	37.0	2.0	7	Medium grey clay loam from sedimentary clays.
5339	1949	0-4	6.7	0.039	2.9	0.20	14	14.8	14.4	97	12.9	1.65	0.04	34	2.4	8.7	39.8	-		
2017	1937	0-6	5.7	0.016				37.9	8.4	22					9.1	15.1	26.9	5.0	12	Greyish brown silt loam from basalt wash, with sedimentary clay subsoil.
5340	1949	0-6	6.7	0.021	2.8	0.29	10	24.2	15.7	65	12.8	2.55	0.80	36	7.6	13.2	31.1	-		
2019	1937	0-6	5.5	0.028				39.1	12.2	31					9.6	15.2	22.3	5.5	13	Greyish dark brown heavy silt loam from a mixture of basalt and sedimentary clay wash.
5341	1949	0-6	6.0	0.038	3.9	0.34	11	27.7	15.8	57	13.1	2.25	0.80	29	6.2	13.9	21.6	0.2		
2021	1937	0-6	5.0	0.038				43.0	9.6	22					8.1	20.6	13.3	6.0	15	Dark grey brown silty clay loam with iron mottling; from sedimentary clays.
5342	1949	0-6	6.3	0.026	3.7	0.31	12	21.7	14.5	67	12.0	1.95	0.95	50	5.4	11.9	30.3	-		

* 1937 analyses are recorded in laboratory with the initials C.I. preceding numbers.

+ Moisture content % of air dry top-soils (105°C).

= Lime required, (tons on acre) to bring top 6 in. to 60 percent Base Saturation.

Discussion

The present study was requested to determine the effect of following for ten years fertilizer recommendations based on the 1937 survey. When the 1949 survey was begun it became apparent that direct comparison of chemical and physical analyses from the two surveys would be misleading because of erosion and the development of a "plough soil."

On cultivated land it is important to distinguish between:

(1) Changes due to erosion and the development of a "plough soil."

(2) The depletion of nutrients by crops and leaching, and the loss of fertility due to physical deterioration caused by cropping and cultivation.

The former changes are usually sudden and complete; for example, a podzolic soil at the foot of a slope may be buried by several feet of brown loam eroded from the slope above.

The latter changes are gradual; where they are the main ones, comparative surveys will provide useful data from which the effects of fertilizer and cultivation practices can be assessed and from which long-term recommendations can be made. But where major changes due to erosion or the development of a plough soil are taking place, the gradual changes cannot be measured. Analyses can be compared for fertilizer recommendations only on a stable soil.

A soil survey carried out when land is under grass may be of use as an aid in predicting the suitability of the land for a new use; but for comparative surveys after the change, a new datum is required—a survey of the soils when they have been stabilized against erosion, and after the "plough soil" horizon has become established.

Judged by ordinary commercial orchard and market garden practice of 14 years ago, this property was not seriously mismanaged; in fact much attention was paid to cover-cropping and the use of fertlizers. Judged, however, by present day standards and in the light of the 1949 survey, the property was seriously mismanaged, for rapid erosion had occurred. Brown loams erode easily and have been observed to move on a 2° clean cultivated slope under heavy rain. On this property slopes as great as 12° were cultivated regularly with rotary hoes which cause considerable downhill movement of soil on slopes and by producing a fine tilth leave the soil in a condition most liable to erode.

The soil changes observed on this property may be taken as typical of what may be expected when soils of these types in the Auckland District are taken from grassland or other "permanent" vegetation and put under intensive cultivation if suitable steps are not taken to prevent erosion at the outset, and if signs of erosion are ignored after they have become apparent.

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STUDIES ON SOME NEW ZEALAND ROMNEY MARSH STUD FLOCKS

PART VI. DRY EWES

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(*Received for publication, 13 December, 1949*)

Summary

(1) An analysis of variations in the percentage of dry ewes by year, age, and stud, has indicated that only the first two are statistically highly significant.

(2) The mean percentage of dry ewes was found to be 10·2. This is composed of 8·0 per cent of once-dry ewes, 2·1 per cent of twice-dry ewes, and 0·1 per cent of thrice-dry ewes.

(3) The following were the percentages of dry ewes by age groups : two-tooth, 16·6 ; four-tooth, 11·2 ; six-tooth, 5·8 ; full-mouth, 5·9 ; and 5½ years and over, 6·0.

(4) The ratio between once-dry and twice-dry ewes was approximately 4 : 1. There were however statistically highly significant yearly differences.

(5) Over four-fifths of twice-dry ewes were dry for the first time as two-tooths.

(6) It has been estimated that : (a) about half of the dry two-tooths, which were kept as four-tooths, would be dry again, and about one-third of them as early as four-tooths ; (b) in spite of culling over many years for various faults and for being dry twice, about one-third of the stud ewes are dry at some time in their life.

Introduction

Ewes which have been put to ram but have not lambed may be divided into two groups : those which have died, or are missing, between tupping and lambing ; and those which are " dry ". The former group was discussed in a previous paper (Goot, 1951), and in this paper the data pertaining to " dry " ewes is analysed.

As no distinction could be made between ewes which aborted and ewes which were barren, a " dry " ewe is defined as a ewe which was put to the ram and which was alive during the lambing season but did not have any offspring. Ewes picked out as empty by teaser rams at the conclusion of tupping are also here included.

The main objects of the investigations were to ascertain : (a) the influence of year, age and stud on the variation in the percentage of dry ewes ; (b) variations in the percentage of once-dry and twice-dry ewes ; and (c) history and subsequent performance of dry ewes.

The paper is based on data pertaining to Studs A and B (Goot, 1946) in which out of 7,585 ewes at mating, 772 or 10·2 per cent were dry in the five years (1941-45) under consideration.

The statistical methods used were Fisher's analysis of variance and chi-square (Snedecor, 1940). All the statistics are of necessity based on unweighted means and this gives an equal weight to both flocks and all age-groups. As not all the sub-classes are adequately represented* and because of the probable binomial distribution of the percentages (Wright, 1948), it was decided to base the analysis of variance on angles corresponding to the percentage of dry ewes (Snedecor, 1940). The partitioning of the variance was based on the method used by Whatley (1941).

* Copies of the full tables have been lodged in the Library of Massey Agricultural College, Palmerston North, New Zealand.

TABLE I. PERCENTAGE OF DRY EWES BY YEAR, STUD AND AGE.

(Percentages based on weighted means.)

Year	Stud	Age*					Total	
		2-tooth	4-tooth	6-tooth	Full Mouth	5½ years and over	No.+	(%)
1941	A	23.2	13.1	6.9	7.3	6.6	198/1,543	12.8
	B	26.8	10.7	4.3	14.3	7.4	54/387	14.0
1942	A	16.5	10.3	7.4	3.9	11.3	112/1,065	10.5
	B	31.3	18.0	12.1	4.7	5.9	66/342	19.3
1943	A	9.4	10.7	2.7	7.4	5.1	76/1,035	7.3
	B	9.9	3.5	4.0	10.5	4.2	20/329	6.1
1944	A	17.9	10.7	5.8	5.7	7.0	104/989	10.5
	B	17.3	10.7	2.5	5.7	2.6	34/364	9.3
1945	A	10.1	12.7	7.1	5.9	3.4	86/1,060	8.1
	B	5.2	7.6	5.4	0.0	2.9	22/471	4.7
Total	A	16.1	11.5	6.1	6.0	6.3	576/5,692	10.1
	B	17.8	10.2	4.8	5.4	4.8	196/1,893	10.4
	A + B	16.6	11.2	5.8	5.9	6.0	772/7,585	10.2

+ Column indicates No. of dry ewes/No. of ewes put to ram. * Age at time of mating.

The literature concerning sterility and abortion in sheep is not extensive. A full discussion is given by Heape (1899), Nichols (1924, 1926a, and 1926b) and some others. The causes of sterility based on actual examination of ewes, were given by Loginova *et al.* (1934), Bludorov and Dubrova (1935a, and 1935b), Polovceva *et al.* (1937), Judovic (1939), and Piening (1942). Broadly, these examinations revealed that the pathological changes or anatomical abnormalities of sexual organs are far from being the chief causes of sterility.

Barton (1947) investigated the fertility of New Zealand Romney Marsh ewes with particular reference to the two-tooth.

RESULTS AND DISCUSSION

Influence of Year, Age and Stud

The percentages of dry ewes according to the year, age and stud are given in Tables I and II. The overall average is 10·2 per cent, the inter-stud difference being statistically non-significant. The analysis of variance of these data is given in Table III. Only difference due to year and age proved to be highly significant; approximately 11 per cent of the total variance has been contributed by the variance due to years, and 43 per cent—four times as much—by the variance due to age. It is also interesting to note that after the age of four-tooth (Fig. 1) the incidence of dry ewes is consistently low.

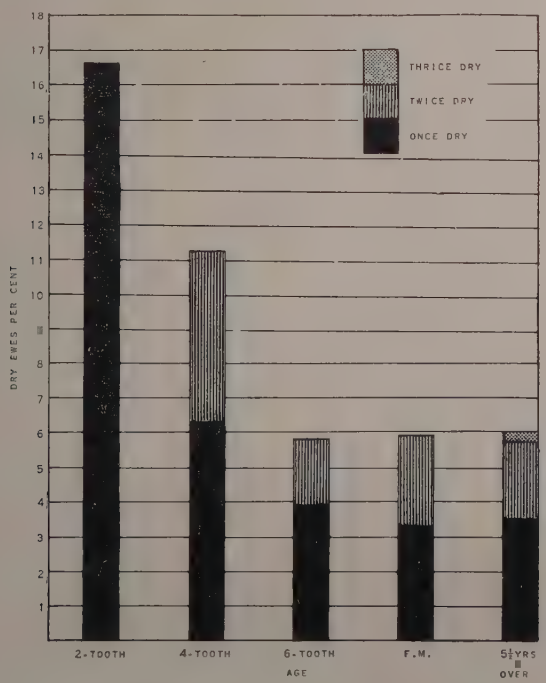

FIG. 1.—Age variation in the percentage of dry ewes.

TABLE II. PERCENTAGE OF DRY EWES IN THE 5½-YEAR OLD AND OLDER GROUPS

Age.	Stud A.	Stud B.
5½ yrs	7·0	5·3
6½ yrs	5·3	5·0
7½ yrs and over	5·7	3·3
Total	6·3	4·8

In Great Britain, Heape (1899) found the percentage of dry ewes in Kent or Romney Marsh to be 6·9; this consisted of 5·5 per cent barren ewes and 1·4 per cent ewes which aborted. Slightly higher figures were recorded by Nichols (1926). The variations within the 15 flocks recorded by Heape were considerable, ranging from 3·9 to 11·1 per cent in the case of barren ewes and from 0 to 3·3 per cent in the case of ewes which aborted. The figures presented in this paper were based on flock-masters' answers to a circular letter and as such do not claim to be representative. It might also be of interest to mention that the average of 6·9 per cent of dry ewes compares quite favourably with the averages for other pure breeds as given by Heape.

In this country the only published paper on dry ewes of New Zealand Romney Marsh breed of which the writer is aware, is that of Barton (1947). His figures, however, are considerably higher than those given above; the difference may be due partly to a slight difference in age composition and partly to the fact that no culling of twice-dry ewes was practised.

That the age of ewes has some bearing on the incidence of dry ewes has been recognized for a long time. Heape (1899) admits that shearling ewes are more liable to abortion than older ones, but he did not find the same to be true with regard to barrenness. Nichols (1926) is of the opinion that both abortion and barrenness are more frequent

TABLE III. ANALYSIS OF VARIANCE OF ANGLES CORRESPONDING TO THE PERCENTAGE OF DRY EWES, BY YEAR, AGE AND STUD.

Variance due to	D.F.	Sum of Squares	Variance	Per cent of total variance
Total " "	49	1,809.57	-	-
Year " "	4	331.66	82.92*	10.74
Age " "	4	801.60	200.40*	43.11
Stud " "	1	9.10	9.10	-
Year-Age	16	346.59	21.66	11.42
Year-Stud	4	108.17	27.04	7.06
Age-Stud	4	22.57	5.64	-
Year-Age-Stud	16	189.88	11.87	27.66

* Highly significant at 1 per cent level.

among younger ewes. Parnell (1939) noted different percentages of dry ewes amongst two, three and four year-old sheep. With the possible exception of Palyakov (1943), nothing more specific has been said about it, as far as the writer is aware, although the influence of age of ewes on the lambing percentage has received considerably more attention.

All the same it is felt that the quantitative assessment of relative importance of age in relation to "year" and "stud" should be regarded as preliminary. This is so partly because the method used for the statistical analysis is not altogether ideal and it is not clear to what extent the results were affected by giving equal weight to age-groups and studs, even though the angular transformation allows for percentages based on small numbers. Further, the observations are not completely independent; nevertheless, as the age differences are outstanding, it seems that they override this difficulty in so far as the main effect is concerned, but of course the interactions might be affected. At present the most that can be said is that there are grounds for suspecting a differential response of "age" and of "stud" to seasonal (year) influences. This is an important point which should be investigated experimentally. In the present data the term "year" covered both environmental and managerial factors which it was not possible to analyse in more detail.

Once-dry and Twice-dry Ewes

Year and Age Variations

The number and percentage of ewes once and twice dry are summarized in Tables IV and V. In view of statistically non-significant inter-stud difference the stud distinction has been abandoned.

The average percentage of dry ewes, 10·2, consists of 8·0 per cent of ewes dry once, 2·1 per cent of ewes dry twice, and 0·1 per cent of ewes dry three times. The latter is due to an insignificant exception to the rule of culling ewes dry twice, occasional exceptions being made in the case of animals particularly valuable in other ways.

As shown in Table IV, nearly 79 per cent of dry ewes were dry once; the highest percentage, 86·2, occurred in 1944, and the lowest, 69·7, in 1942. Conversely the highest percentage of twice-dry ewes, 29·2, occurred in 1942, and the lowest 13·8, in 1944. The yearly variations were found to be statistically highly significant ($\chi^2 = 17{\cdot}62$; d.f. $= 4$). As they do not seem to be associated with the yearly variation in the number of two-tooth and four-tooth ewes, they must be attributable to seasonal influences.

The age-group variations in the once-dry and twice-dry ewes are shown in Table V. When the two-tooths are excluded, as they must be, the differences between the remaining age-groups are statistically non-significant ($\chi^2 = 2{\cdot}65$; d.f. $= 3$). It is of considerable interest to note that when the two-tooths are excluded the mean percentage of all dry ewes decreases from 10·2 to 7·5, and of once-dry ewes from 8·0 to 4·4 per cent. However, the percentage of twice-dry ewes increases slightly from 2·2 to 3·1 per cent. In other words, when two-tooth ewes are excluded the ratio between once-dry and twice-dry ewes changes from 4 : 1 to 3 : 2. The latter ratio does not differ significantly amongst the age-groups.

TABLE IV. NUMBER AND PERCENTAGE OF EWES, IN STUDS A AND J WHICH WERE DRY ONCE OR MORE, ACCORDING TO YEAR

Year		Once dry	Twice dry	Total
19-	No.	210	42	252
	% 1	10.9	2.2	31.1
	% 2	83.3	16.7	100.0
19-2	No.	124	54*	178
	% 1	8.6	3.8	12.6
	% 2	69.7	30.3	100.0
19-3	No.	71	25*	96
	% 1	5.2	1.8	7.0
	% 2	74.0	26.0	100.0
19-4	No.	119	19	138
	% 1	8.8	1.4	10.2
	% 2	86.2	13.8	100.0
19-5	No.	83	25	108
	% 1	5.4	1.6	7.0
	% 2	76.9	23.1	100.0
All	No.	607	165	772
	% 1	8.0	2.2	10.2
	% 2	78.6	21.4	100.0

[1]percentage based on number of ewes put to the ram in each year.

[2]percentage based on number of dry ewes in each year.

* includes 2 ewes dry three times.

Age-composition of dry ewes

The age composition of dry ewes is shown in Table VI. For comparison, average composition of ewes put to ram is also given. Of the once-dry ewes the two-tooths contributed just over 61 per cent, the four-tooths 17 per cent and the remaining age-groups between 6 and 9 per cent each. Thus the two youngest age-groups, comprising slightly more than 50 per cent of all the ewes, contributed nearly 80 per cent of the once-dry ewes.

Of the twice-dry ewes the four-tooths contributed nearly one half, and the older age-groups between 16 and 19 per cent each. Of all the dry ewes, nearly one half were dry as two-tooths.

These figures bring out the importance of the age-composition of the flock and, in comparing the incidence of dry ewes between flocks, it is obvious that the age-composition of the flocks must be taken into consideration if valid comparisons are to be made.

TABLE V. NUMBER AND PERCENTAGE OF EWES IN STUDS A AND B WHICH WERE DRY ONCE OR MORE ACCORDING TO AGE-GROUPS.

Age Group		Once dry	Twice dry	Total
2-tooth	No.	371	-	371
	% 1	16.6	-	16.6
4-tooth	No.	103	80	183
	% 1	6.3	4.9	11.2
	% 2	56.3	43.7	100.0
6-tooth	No.	54	27	81
	% 1	3.9	1.9	5.8
	% 2	66.7	33.3	100.0
Full-Mouth	No.	34	26	60
	% 1	3.3	2.6	5.9
	% 2	56.7	43.3	100.0
5½ years and over	No.	45	32 *	77
	% 1	3.5	2.5	6.0
	% 2	58.4	41.6	100.0
All except 2-tooth	No.	236	165	401
	% 1	4.4	3.1	7.5
	% 2	58.9	41.1	100.0

[1]percentage based on number of ewes put to the rams in each group.

[2]percentage based on number of dry ewes in each age-group.

* includes 4 ewes dry three times.

Age and the Incidence of Twice-dry Ewes

Ewes which were dry twice were not necessarily dry in two consecutive years, although in at least half the cases this was so. Fig. 2 shows the age at which these ewes were dry for the first time. It will be seen that 83 per cent of twice-dry ewes were dry for the first time as two-tooths, 10 per cent as four-tooths, leaving only 7 per cent for the remaining ages.

As just over four-fifths of twice-dry ewes were dry first at the age of two-tooth, the question naturally arises as to how many of the dry two-tooths were dry again. Owing to the lack of sufficient data no direct and complete answer is possible at present, except perhaps in the case of four-tooths. There were 336 dry two-tooths in the 1941-44 seasons; of these, 218, or 65 per cent, were kept as four-tooths, the

others being culled for various faults. Out of those 218 dry ewes, 63, or nearly 29 per cent, were dry again as four-tooths. It is estimated that a further 20 per cent or so were dry for the second time as six-tooth and older ewes. Thus in spite of culling in succeeding age-groups of some of the original dry two-tooths which were kept in the stud as four-tooths, up to one half is dry again some time during their productive lifetime, and about one-third as early as four-tooths. On the other hand, if a ewe older than a two-tooth is dry for the first time, it is estimated that she has no more than a 1 in 5 chance on the average of being dry again.

TABLE VI. PERCENTAGE AGE COMPOSITION OF DRY EWES

Age Group	Age composition of ewes at mating		Breeding condition of ewes		
	All	2-tooths excluded	Once-dry	Twice-dry	Total
2-tooth	29.5	-	61.1	-	48.1
4-tooth	21.6	30.6	17.0	48.5	23.7
6-tooth	18.5	26.2	8.9	16.4	10.5
Full-mouth	13.4	19.1	5.6	15.7	7.8
5½ yr and over	17.0	24.1	7.4	19.4	9.9
Total No.	7,585	5,345	607	165	772

Another point of considerable interest is the estimated percentage of dry ewes over the lifetime of the ewes. Basing the calculation on the statistics given in this study, and taking into consideration culling rates, mortality, etc., it can be shown that out of, say 100 two-tooth ewes which enter the stud there will be, on the average, 16·6 dry as two-tooths, 8·8 dry as four-tooths, 3·5 dry as six-tooths, 2·8 dry as full-mouths and 2·4 dry ewes as 5½-year-olds, giving a total of 34 dry ewes. Considering that the twice-dry ewes are culled, this is indeed a high proportion of infecundity.

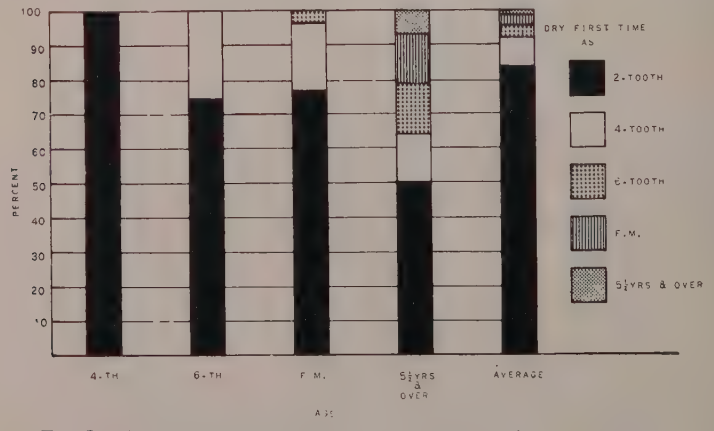

FIG. 2.—Age at which the twice-dry ewes were dry for the first time.

CONCLUSION

The scope of this study was conditioned by the data available, and although the results refer to the two commercial stud-flocks, the main findings have a much wider significance. The two outstanding, but not entirely unexpected, results brought out in this study, namely, that (a) the incidence of dry ewes is high, and (b) that the age, particularly of two-tooths, is a very important factor in the high incidence of dry ewes, should be strongly emphasized. It is therefore obvious that in order to decrease the high percentage of dry ewes, factors bringing about barrenness and abortion in two-tooth ewes in particular must be investigated and then eliminated if possible.

The problem of lambing percentage will be discussed in the subsequent paper.

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STUDIES ON SOME NEW ZEALAND ROMNEY MARSH STUD FLOCKS

PART VII. LAMBING PERCENTAGE

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Summary

(1) The paper presents results of an investigation on some factors affecting the lambing percentage in two New Zealand Romney Marsh stud-flocks; it is based on data pertaining to 7,585 breeding ewes and 9,183 lambs born in 1941-45 seasons.

(2) A correlation coefficient ($r = -0 \cdot 79$) has been established between the percentage of dry ewes and the lambing percentage.

(3) There was no correlation between the lambing percentage and the mortality either in ewes or in lambs

(4) A correlation coefficient ($r = 0 \cdot 91$) has been established between the percentage of multiple births and the lambing percentage.

(5) Influence of year, age and stud on the lambing percentage and the multiple births has been statistically analysed. Age proved to be the most important variance accounting for 67 and 72 per cent respectively of the total variance.

The two-tooth is the least and the full-mouth the most prolific age group.

Introduction

The term "lambing percentage" has been variously used in the literature on the subject, but in this country the most common interpretation is the percentage of lambs docked per ewes put to ram. Throughout the paper this term will be used as defined above, unless otherwise stated. It is, nevertheless, clearly recognised that the choice is more or less arbitrary, and to enable the computation of other measures of fecundity the basic data are summarized in Tables I and II.

Factors affecting the lambing percentage are discussed under the following headings; dry ewes, mortality in ewes, mortality in lambs and multiple births. In addition, the statistical analyses on variation in lambing percentage and multiple births by year, age and stud are given.

The paper is based on data for five years (1941-45), during which 7,585 breeding ewes were put to the rams and 9,183 lambs were dropped in Stud-flocks A and B (Goot, 1946).

The literature concerning the factors influencing fertility in sheep, with a full discussion, has been given by Nichols (1924, 1926 and 1927), Briggs *et al.* (1942) and others.

Some Factors Affecting the Lambing Percentage

In order to ascertain the general relationship between the lambing percentage and the incidence of dry ewes, mortality rate, etc., it was decided to use a simple correlation and regression technique in preference to any more refined methods. All the statistics are of necessity based on unweighted means, and hence equal weight is given to both studs and all age-groups. As there were 5 years, 5 age-groups, and 2 studs the statistics are based on 48 degrees of freedom. It should also be pointed out that the correlation coefficients, owing to a certain degree of overlapping, tend to over-estimate the relationships measured. A correction (Peters and Van Voorhis, 1940) would at this stage be a superfluous refinement, as no attempt is made to interpret the statistical findings in terms of biological phenomena.

TABLE I. NUMBER OF EWES, LAMBS AND MULTIPLE BIRTHS IN STUDS A AND B ACCORDING TO SEASON

Year	Stud	Ewes put to ram [1]	Ewes lambing	Lambs born	Lambs docked	Multiple births		
						Twin births	Triplet births	Total
1941	A	1543	1310	1773	1602	435	14	449
	B	387	327	473	402	134	6	140
1942	A	1065	945	1311	1150	330	18	348
	B	342	252	361	333	107	1	108
1943	A	1035	932	1273	1117	307	17	324
	B	329	303	466	398	143	10	153
1944	A	989	842	1148	1002	278	14	292
	B	364	321	455	384	126	4	130
1945	A	1060	946	1331	1201	357	14	371
	B	471	440	592	502	146	3	149
TOTALS	A	5692	4975	6836	6072	1707	77	1784
	B	1893	1643	2347	2019	656	24	680
	A & B	7585	6618	9183	8091	2363	101	2464

1 Includes in-lamb ewes which were brought in, but excludes ewes sold at any time before lambing commenced.

TABLE II. NUMBER OF EWES, LAMBS AND MULTIPLE BIRTHS IN STUDS A AND B ACCORDING TO AGE

Age *	Stud	Ewes put to ram	Ewes Lambing	Lambs born	Lambs docked	Multiple births		
						Twin births	Triplet births	Total
2-tooth	A	1623	1338	1643	1381	293	6	299
	B	617	500	627	520	127	0	127
4-tooth	A	1206	1058	1442	1290	358	13	371
	B	431	376	525	473	143	3	146
6-tooth	A	1048	956	1373	1235	379	19	398
	B	353	323	489	436	156	5	161
Full-mouth	A	779	713	1041	943	298	15	313
	B	240	218	339	288	103	9	112
5½ years	A	542	482	717	651	201	17	218
	B	132	121	201	170	76	2	78
6½ years	A	285	249	369	340	116	2	118
	B	60	53	90	76	29	4	33
7½ years & over	A	209	179	251	232	62	5	67
	B	60	52	76	56	22	1	23
TOTALS	A	5692	4975	6836	6072	1707	77	1784
	B	1893	1643	2347	2019	656	24	680
	A + B	7585	6618	9183	8091	2363	101	2464

* At mating

Dry Ewes

The problem of dry ewes has already been discussed in a previous paper (Goot, 1952); in this paper the effect of dry ewes on the lambing percentage is examined. A correlation between the percentage of dry ewes and lambing percentage proved to be highly significant, linear and negative ($r = -0{\cdot}792$; $by{\cdot}x = -2{\cdot}16 \pm 0{\cdot}21$). Thus a decrease of dry ewes by 1 per cent would, on the average, increase the lambing percentage by 2·16 and *vice versa*, the changes being linear within the limits measured, viz. 0-31 per cent of dry ewes.

The value of the above correlation coefficient is higher than that given by Nichols (1926a) for Southdown, but not as high as those for Cheviot and Blackface sheep (Nichols, 1927a).

Culling of dry two-tooths

It has been shown previously (Goot, 1952) that, all other factors being equal, culling of the dry two-tooth ewes would reduce the twice-dry ewes by 83·2 per cent. This in turn would reduce the average percentage of dry ewes in the flock from 10·2 to 8·4, a decrease of 1·8 per cent. The average effect of this decrease would be an increase in lambing percentage of 3·9.

Mortality in ewes and lambs

The correlation between the mortality of ewes between tupping and lambing, including ewes which died at parturition (Goot, 1951), and the lambing percentage, $r = 0{\cdot}06$, proved to be statistically not significant. Similarly a correlation between the percentage of lambs which died before docking, based on the number of ewes put to the ram, and the lambing percentage, $r = 0{\cdot}11$, is statistically not significant. It appears therefore that the variation in the mortality of the ewes and lambs in the present study is of minor importance in comparison with such factors as dry ewes, multiple births, season, etc.

Fertility of ewes which died after parturition

Figures pertaining to the fertility of ewes which died after parturition (Goot, 1951), along with similar figures based on all the ewes in the two flocks, are given in Table III. In this comparison, of course, all the percentages are based on ewes lambed. With ewes which died after parturition there was an appreciably higher average percentage of lambs born and of multiple births, very much higher mortality rate of lambs before docking, and consequently a very much lower percentage of lambs docked. As the higher percentage of lambs born is due entirely to the higher incidence of multiple births, it is of fundamental interest to know whether and to what extent the higher incidence of multiple births is counteracted by a lower survival rate. In other words, and more broadly, what effect has mortality associated with pregnancy on the selection for higher fertility ?

Again, as the lower percentage of lambs docked is due to higher mortality of lambs before docking, it is important to know how many of these were still-born, and how many died as a consequence of losing their mothers. These losses, as any others, may be influenced by management (Peren, 1947). However, the fact remains that only about half of the lambs born from ewes which died after parturition reached the docking age, whereas, on the average, over 92 per cent of lambs born from all ewes which lambed were docked. The difference is striking. These problems should be comprehensively investigated; they are important economically and have a number of biological ramifications.

TABLE III. COMPARISON BETWEEN FERTILITY IN EWES WHICH DIED AFTER PARTURITION AND ALL THE EWES IN STUDS A AND B IN 1941-45 SEASONS

Age-Group	Percentage Lambs per Ewes Lambing			
	Lambs born	Lambs docked	Lambs having died before docking	Multiple births
Ewes which died after parturition[1]				
2-tooth	137.2	55.8	81.4	34.9
4-tooth	173.7	105.3	68.4	63.2
6-tooth	148.4	71.0	77.4	45.2
Full-mouth	147.0	94.1	52.9	47.1
5½ yrs & over	170.5	102.9	67.6	61.8
Average	153.5	81.3	72.2	48.6[2]
All Ewes				
2-tooth	113.5	103.4	10.1	23.2
4-tooth	137.2	122.9	14.3	36.1
6-tooth	145.6	130.6	15.0	43.7
Full-mouth	148.2	132.8	15.4	45.6
5½ yrs & over	150.0	134.2	15.8	47.3
Average	138.8	122.3	16.5	37.2[3]

[1]Period 2b (Goot, 1949a)

[2]Twin births: 43.8%, triple births: 4.8%.

[3]Twin births: 31.2%, triple births: 1.3%.

Multiple births

There is a highly significant correlation between the percentage of multiple births and the lambing percentage ($r = 0{\cdot}9099$; Log $Y = 0{\cdot}3754 \log x + 1{\cdot}4603$; Log $Se = 0{\cdot}0292$). For reasons explained, in the subsequent section the statistics were based on unweighted means of logarithms. It will be noted that over 80 per cent of variation in the lambing percentage is associated with the differences in the percentage of multiple births, and therefore the latter must be regarded as the most important single factor influencing the lambing percentage. This is in full agreement with observations of Heape (1899), and statistics given by Nichols (1926a). In passing, it might be of interest to note that there is a highly significant linear and negative correlation between the percentage of dry ewes and the percentage of multiple births ($r = -0{\cdot}56$ by·x $= 1{\cdot}1627 \pm 0{\cdot}2924$).

Variation in Lambing Percentage and in Multiple Births By Year, Age and Stud

In order to ascertain the effect of the year, age and stud on the variations in lambing percentage and multiple births, Fisher's analysis of variance (Snedecor, 1940) was used. The variance components due to the different factors were expressed as percentages after the method used by Whatley (1941). Because the standard deviations of groups were roughly proportional to the group means, it was necessary to transform the original data into logarithms (Winsor and Clarke, 1940).

The analyses of variance were of necessity based on the unweighted means of logarithms. This gives an equal weight to both studs and all age-groups. In the former case, the fact that the means are not biassed toward the figures of the bigger stud might be advantageous ; Stud B, being the smaller one, might be in many ways more typical.

Whether the same reasoning could apply to age-groups is not so certain (Goot, 1952). When each age-group weighs equally, the variations in the age-composition of a stud are eliminated. On the other hand, an age-group which is small in numbers weighs as much as one well represented. This should, however, be of minor consequence in this study because the less numerous age-groups were treated as one (ewes $5\frac{1}{2}$-years-old and over), and further, the biggest differences were found between two-tooths and older age-groups rather than between any of the older age-groups.

Yearly variations

Under this term are grouped those factors, common to both studs and all ages, which are responsible for yearly differences in the lambing percentage and the percentage of multiple births. Such factors as temperature, rainfall, kind and quality of food, etc. will be environmental ; they also include the effect of management common to both studs and such portion of hereditary factors as may change from year to year. It should be pointed out, however, that factors not common to both studs will be grouped under the " stud " and the interactions.

The differences between years were highly significant for the lambing percentage only. The deviations from the mean in those five years are comparatively small. The range in the values of the lambing percentage based on the antilogarithms of unweighted means is from 105·9 to 116·8 with the mean at 109·3 ; the range in the multiple births is even smaller, being from 32·4 to 38·6 per cent with the mean at 34·4 per cent.

Taking the flocks individually (Fig. 1), it will be seen that Stud B shows much bigger variations than Stud A ; a still more striking fact is that there was not a single year during which either maximum or minimum values in one flock coincided with a similar value in the other. As the farms are close to each other the climatic and to a lesser extent soil conditions are very much alike (Goot, 1946); it seems, therefore, very likely that the yearly variations in the lambing percentage are in no small way due to the differences in the management of the two stud farms ; these are, no doubt, reflected in the significant year-stud interaction.

Variations according to age

The ewes were divided into five age-groups, the last group consisting of ewes of various ages from $5\frac{1}{2}$ to $12\frac{1}{2}$ years old. The grouping together brought about a very slight decrease in the value of the lambing per-

centage due to the decrease in fertility beginning with $7\frac{1}{2}$-year-old ewes. As only one-fifth of this group consists of $7\frac{1}{2}$-year-old and older ewes, and as the lambing percentage of the $5\frac{1}{2}$- and $6\frac{1}{2}$-year-old ewes was practically the same (Table II), the slight decrease is of no practical importance.

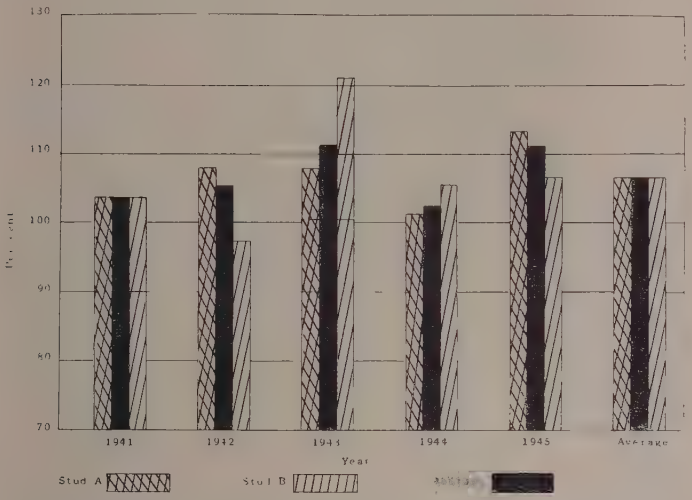

FIG. 1.—Lambing percentage by year and stud ; based on weighted means.

Age proved to be highly significant for both measurements. The variations due to ageing, i.e. those due to physiological phenomena not associated with the year, stud, or any joint factors thereof, contributed to the total variance between 66·8 and 72·3 per cent. In addition to that, a portion of the variance which was associated with the " year " (year x age interaction) proved to be significant in the case of the lambing percentage, and accounted there for an additional 10 per cent of the total variance. According to the present study, age is thus by far the most important single factor influencing the lambing percentage and the incidence of multiple births.

Table V shows the mean fertility in each age-group, and Figs. 2 and 3 illustrate the age variations in each of the stud-flocks. It will be seen that : (i) the two-tooth is the least, and the full-mouth the most prolific age-group ; (ii) the biggest rise in both lambing percentage and multiple births occurs at the four-tooth, and to a lesser extent at the six-tooth stage ; and (iii) if the prolificacy of the two-tooths is taken as 1·00 then the most prolific ages have relative values of 1·42 for the lambing percentage and 2·19 for the multiple births (Dry, 1936). Incidentally it is of interest to note that the values of lambing percentage and multiple births of the four-tooths approximate rather closely the values for the whole flock. It is quite possible that the four-tooth may give a reliable estimate of the lambing percentage of the whole flock. Such a short cut might be of value under certain circumstances.

TABLE IV. SUMMARY OF THE RESULTS OF THE ANALYSES OF VARIANCE IN LAMBING PERCENTAGE AND THE PERCENTAGE OF MULTIPLE BIRTHS BY YEAR, AGE AND STUD
(Based on logarithms of the original data from 7,585 ewes and 9,183 lambs; the variance and components of variance were multiplied by 1,000,000)

Variance due to	D.F.	Lambing percentage			Multiple births		
		Variance	Components of Variance	Per cent of total variance	Variance	Components of Variance	Per cent of total variance
Year	4	3,450**	..	..	8,425	..	..
Age	4	43,950**	4,244	72.3	244,350**	23,540	66.8
Stud	1	100	..	..	44,000*	1,304	3.7
Year x Age	16	1,856*	616	10.5	11,163	2,138	6.1
Year x Stud	4	2,550*	385	6.6	13,625	1,347	3.8
Age x Stud	4	275	..	..	4,675	..	..
Year x Age x Stud	16	625	625	10.6	6,888	6,888	19.6

* Significant at 5% level

** Highly significant at 1% level

Variations according to Stud

There was no difference in the lambing percentage between Studs A and B, but the difference in the incidence of multiple births proved to be statistically significant: 31·3 per cent in Stud A, and 35·9 per cent in Stud B. This may possibly be due partly to the less careful recording of multiple births in the bigger Stud A, and partly to the higher incidence of multiple births in Stud B, particularly in the older age-groups. (Table II and Fig. 3). Thus the latter flock can probably be credited with more lambs being born, but must be debited with their higher mortality before docking (Goot, 1951), so that at docking the lambing percentages are substantially the same.

TABLE V. LAMBING PERCENTAGE AND MULTIPLE BIRTHS BY AGE, BASED ON WEIGHTED MEANS (Figures in brackets refer to the antilogarithms of unweighted means).

Age *	Lambing percentage		Multiple births	
	%	2-tooth = 1.0	%	2-tooth = 1.0
2-tooth	84.9	1.00	19.0	1.00
	(84.1)		(19.0)	
4-tooth	107.7	1.27	31.6	1.66
	(108.5)		(31.7)	
6-tooth	119.3	1.41	39.9	2.10
	(118.3)		(40.0)	
Full-mouth	120.8	1.42	41.7	2.19
	(120.4)		(43.4)	
5½ yrs and over	118.4	1.39	41.7	2.19
	(120.0)		(45.9)	
Average	106.7	1.26	32.5	1.71
	(109.3)		(34.4)	

* At mating

DISCUSSION AND CONCLUSION

Because of lack of more extensive factual information, it is impossible at present to discuss more fully the question of fertility in New Zealand Romney Marsh sheep; but as the lambing percentage is one of the most important factors in sheep production it is considered necessary to draw attention to a few relevant points. In doing this, it is more useful to focus attention on the background than to make comparisons. What perhaps should be stressed at the outset is the fact that the original Kent or Romney Marsh breed was apparently not as prolific as, say the Suffolk or Wensleydale breed (Heape, 1899), and it is still more important that the present day New Zealand Romneys, as represented in this study, have obviously not been improved in this respect over the last half century. Fifty years ago, Heape(1899) divided the British

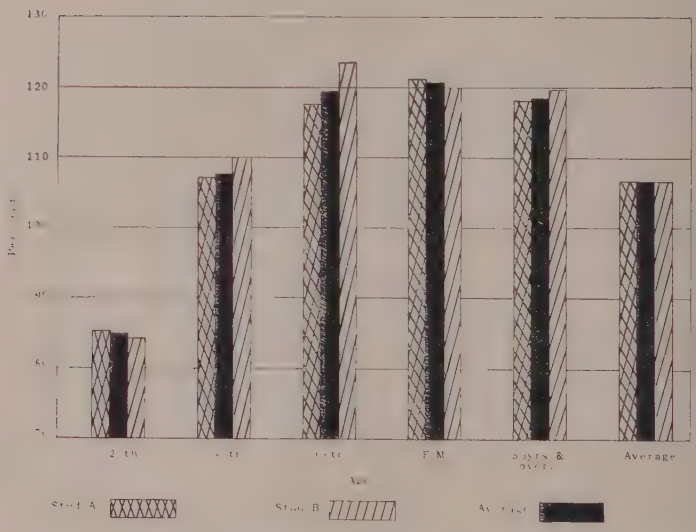

FIG. 2.—Lambing percentage by age and stud ; based on weighted means.

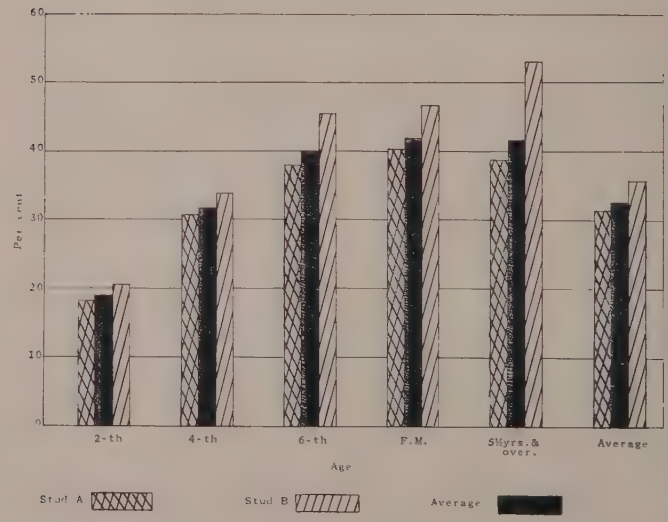

FIG. 3.—Multiple births by age and stud ; based on weighted means.

breeds of sheep into three classes of fertility, the Kent being placed in the second class with a 124·1 per cent crop of lambs and 31·4 per cent of twin births. His figures, pertaining to 8,481 ewes and 10,521 lambs in 13 flocks, were unfortunately based not only on the number of lambs born, but also on the number of lambs docked or " alive at the time the circular was filled up ". He finds, therefore, the return of twinning much more reliable and claims that " by its help one is able to arrive at a fairly accurate idea of the correctness of the lambing returns and of the relative fertility of the different breeds ". Heape's figures could be roughly compared with the percentage of lambs born per ewes put to ram, viz. 121·1, and with the 32·5 per cent of multiple births per ewes put to ram. In this connection the only two other references found in the literature might be cited: Nichols (1926b) gives a lambing percentage for one flock of Romney Marsh in Great Britain as 128·5; Barton (1947) calculated the percentage of lambs dropped in one New Zealand Romney Marsh stud-flock over the 1933-45 period; his average figure when converted by means of a regression equation (Goot, 1949) equals 124·1 per cent of lambs *born* from the ewes put to ram.

Further, as the overwhelming majority of breeding ewes in the North Island of New Zealand (probably over 95 per cent), are either of Romney breed, or predominantly Romney, it is of considerable interest to know that the lambing percentage (" lambs tailed per 100 breeding ewes as at the previous 30th April ") in the North Island varied during the 1920-45 period from 80·7 to 94·8 with " a general tendency to rise as might be expected as sheep farming moves to fat lamb production on the more intensely managed pasture lands " (1947). The unweighted average is 87·6 lambs tailed per 100 breeding ewes. In other words, the lambing percentage in Studs A and B was just over 20 per cent higher than the North Island average. However, it is generally conceded that the lambing percentage in studs is higher than in flocks, the difference being probably due mostly to the environment and management. But even under stud-farm conditions the lambing percentage is grossly depressed by the presence of dry ewes and by the mortality in lambs. From Table I it can be seen that from the ewes lambing, 138·8 per cent of lambs were born. Based on the number of ewes put to the ram, however, this figure was reduced to 121·1 per cent, while the percentage of lambs docked was only 106·7 per cent. Thus 17·7 per cent of potential lambing percentage was lost due to failure of ewes to lamb, and 14·4 per cent due to still-births and mortality of lambs prior to docking, making a total of 32·1 per cent. Herein lies the most obvious approach to the problem of improving the lambing percentage.

Finally, it should be noted that the results of the investigation here reported relate only to the stud flocks considered, and as such they may not be representative of the New Zealand Romney Marsh stud-flocks as a whole.

ACKNOWLEDGMENTS

The author's thanks are due to Mr. E. A. Clarke for helpful suggestions; to Mr. G. M. Wright for advice on some statistical problems; to Mr. H. Nevill for valuable help in analysing the raw data; and to Miss B. S. Bowden for her assistance during the preparation of this paper.

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BLIND-SEED OF RYEGRASS

III. EFFECT OF FUNGICIDES ON THE DISEASE

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(*Received for publication, 20 July 1951*)

Summary

(1) An account is given of methods used for inoculating and assessing the degree of infection of perennial ryegrass by blind-seed disease (*Phialea temulenta* Prill and Delacr.)

(2) It was shown that infection could be secured but a considerable variation in degree of infection occurred.

(3) Germination counts provided the most reliable index of infection. Assays from either microscopic examination of seed or from seed grown in culture media were not satisfactory.

(4) Several fungicides were tested as sprays and dusts. Under conditions of the experiments it was found that sprays of Bordeaux mixture 10-8-100, Phygon 1 lb 100 gal water, and Dithane D.14 4 lb 100 gal, and copper carbonate dust (23 per cent copper) all gave measurable control of the disease.

Introduction

For export purposes, certified perennial ryegrass must have a minimum germination of 90 per cent. The data of Neill and Hyde (1939, 1942) and Hyde (1945) showed that in almost every season, in some localities at least, many crops failed to reached this standard. It was further demonstrated (Neill and Hyde, loc. cit.; Calvert and Muskett, 1945) that a major cause of low germination was infection by blind-seed disease (*Phialea temulenta* Prill and Delacr.). Control of this disease has therefore become a problem of considerable economic importance.

Two methods of control of blind-seed disease are at present being investigated, viz. by farm management (Gorman 1940, 1945; Wilson, Noble and Gray, 1945), and by breeding for resistance (Corkill and Rose, 1945). A third possible method of control is by use of fungicides at the time of flowering of the crop. The present paper reports on preliminary investigations into this method.

Experimental Procedure

Growing of Plants

Plants were raised from a single high-germinating line of Hawke's Bay perennial ryegrass seed. They were grown in sterilised soil, pricked out into pots which were placed in an unheated glasshouse, hardened off and finally sunk into bedding soil in the open. Pots were lifted as required for treatment.

Preparation of Spray Materials

Bordeaux Mixture: 10 lb copper sulphate (98 per cent), plus 8 lb calcium hydroxide (95 per cent) to 100 gal water.

Colloidal Sulphur: A paste in water containing 40 per cent sulphur, used at 4 lb to 100 gal water.

Phygon: A proprietary compound of dichloro-naphthoquinone containing 98 per cent active ingredients and used at 1 lb to 100 gal water.

Dithane D.14: A proprietary solution in water containing disodium-ethylene-bisdithiocarbamate-hexahydrate, 25 per cent active ingredients, used at 4 lb to 100 gal water.

Preparation of dust materials

Copper Carbonate: Containing approximately 23 per cent copper.

Sulphur: Micronized sulphur, applied without dilution.

Phygon: The concentrate described above, ground with kaolin as diluent to give a dust containing 1 per cent phygon.

Preparation of Inoculum

Blind-seed inoculum was obtained from a low-germinating (25 per cent) line of perennial ryegrass seed. Seed was deglumed, surface-sterilised, bisected and plated on prune-dextrose agar. Isolates of *P. temulenta* were transferred to potato-dextrose agar slopes in flat 6-oz bottles. Abundant macroconidial slime was produced within 8-14 days, each bottle providing ample inoculum for 12 plants.

Treatment and Inoculation of Plants

There was a considerable variation in flowering dates between individual plants. Consequently only a limited number of plants was ready for treatment at any one time. It was therefore necessary to apply each fungicide to groups of plants at different periods with the result that each treatment had to be conducted as a separate experiment.

For this purpose, groups of 14 plants were selected for uniformity from the bulk population and placed in a glasshouse for one to two days to hasten mid-flowering. This stage of blooming was recognised by the opening of one or more florets in the majority of spikelets over the entire spike. Application of fungicide and/or inoculum at this period ensured direct contact with the maximum number of florets per plant. Plants were trimmed immediately prior to the experiment to leave 6-12 heads per plant.

Each group was subdivided as follows:—

(*a*) *Treated-inoculated*: Six plants were sprayed or dusted at midday. Spraying was by a hand atomizer to give even wetting. Dusts were applied by a De Vilbiss duster to give a thorough deposition over the flowering heads.

In the late afternoon, plants were inoculated with a concentrated suspension of blind-seed macroconidia in sterile water, applied by a hand atomizer.

(*b*) *Inoculated Check*: Six check plants were inoculated only as above.

(*c*) *Uninoculated Check*: Two plants were sprayed with sterile water only.

Plants subjected to each of the three treatments were kept separate and immediately transferred to glass humidity chambers resting in trays in the open. For protection against direct sunlight, the tops of these cabinets were, if necessary, covered with scrim. After 24 hours, treated-inoculated and inoculated check plants received a second inoculation, and the uninoculated check plants a further spraying with

sterile water. This was followed by an additional 24-hour period in the chambers. Despite the high humidity maintained over the total 48-hour period, flowering appeared to continue normally in all plants.

At the close of the incubation period plants were sunk in the ground in a semi-shaded situation with the uninoculated check plants isolated from the other treatments. To prevent lodging and minimise infection by secondary fungi, plants were staked. Later they were bagged for seed collection, and at ripening were harvested and hand-threshed.

TABLE I. - EFFECT OF FUNGICIDES ON BLIND-SEED DISEASE OF RYEGRASS. PLANTS INFECTED BY ARTIFICIAL INOCULATION WITH PHIALIA TENULENTA

Treatment *	Date of Application	Germination ** (%)	Significant difference	"Blind" seed+ (%)
SPRAYS				
A. Bordeaux 10-8-100	19-21/12/46	66	18.1	52
B. Check	"	37	16.0	87
Difference for Significance at 5% level		22.7		
A. Colloidal Sulphur	23-25/12/46	36	17.7	90
B. Check	"	51	31.3	74
Difference for Significance at 5% level		32.5		
A. Phygon	8-10/1/47	89	4.6	26
B. Check	"	53	9.9	80
Difference for Significance at 5% level		8.9		
A. Dithane	10-12/1/47	78	17.3	57
B. Check	"	58	16.8	73
Difference for Significance at 5% level		20.6		
DUSTS				
A. Copper Carbonate	18-20/1/47	95	2.0	15
B. Check	"	78	9.3	38
Difference for Significance at 5% level		11.7		
A. Sulphur	21-23/1/47	74	18.3	22
B. Check	"	78	11.6	38
Difference for Significance at 5% level		25.7		
A. Phygon	24-26/1/47	81	16.3	17
B. Check	"	78	13.1	19
Difference for Significance at 5% level		36.5		

* A. Sprayed or dusted and inoculated
B. Inoculated only

** 12-day test; each figure the mean for six plants.

\+ Estimated from the microscopic examination of 30 seeds per plant; each figure the mean for six plants.

Measurement of Results

The following methods were used to measure the degree of infection of seed by *P. temulenta*:—

(*a*) *Germination counts*: These were standard 12-day tests carried out by courtesy of the Seed Testing Station, Department of Agriculture, Palmerston North. It was considered that such counts would give an index to amount of disease present as Calvert and Muskett (1945) showed that varying degrees of infection with *P. temulenta* resulted in a proportionately reduced germination.

(*b*) *Microscopic examination of seed for presence of macroconidia of the fungus*: Seeds (a random sample of 30 per plant) were partially deglumed, lightly scratched with a sharp scalpel, and the scrapings examined.

(*c*) *Reisolation of P. temulenta in culture from seed of inoculated plants*: A random sample of 30 seeds per plant were cultured by the procedure of Neill and Hyde (1939), already described.

RESULTS

Results of germination counts and of microscopic examination of seed from treated and check plants are given in Table I.

The germination of uninoculated check plants ranged from 93 to 98 per cent. Microscopic examination failed to reveal the presence of *P. temulenta* in seeds of any of these plants.

DISCUSSION

The methods employed demonstrated that it is possible to inoculate ryegrass artificially with blind-seed disease. Variations in percentage infection occurred, however, both between plants inoculated at the same time and in different experiments. It is probable that more consistent results would be obtained by:—

(*a*) Use of plants derived from the seed of one original plant.

(*b*) Incorporation of all treatments in one experiment.

(*c*) Standardisation of inoculum applied to each plant.

(*d*) More adequate control of temperature and humidity during the incubation period.

Of the three methods employed for ascertaining amount of infection, that based on germination counts gave the most satisfactory results. It does not, however, take into account the possible deleterious effect of certain fungicides on seed setting. Thus spray treatment with colloidal sulphur reduced germination as compared with that of check plants. Although the difference was not significant it is possible that seed setting was adversely affected, as sulphur has been shown to damage flowers of other crops. Thus Pape and Engelhardt (1936) demonstrated sulphur damage to flowers of greenhouse vetches, and Lewis (1942) recorded reduction in fruit setting of apples treated at full bloom with sulphur. Estimation of infection by microscopic examination has the disadvantage that it is tedious, subject to errors of observation, and does not reflect germination capacity. Measurement of degree of infection based on percentage of seed showing *P. temulenta* in culture is confused by the presence of contaminant fungi. Although abandoned as a method of estimation, it was used to confirm the presence of *P. temulenta* in inoculated plants.

In the light of the analyses made it is clear that under experimental conditions a measure of control of blind-seed disease can be secured. There was a significant response to use of Bordeaux spray, 10-8-100 and copper carbonate dust, while Phygon spray produced a highly significant reduction in amount of infection (difference for significance at 1 per cent level = 13.4 per cent; actual difference = 36 per cent). Dithane spray reduced infection, although the difference between sprayed and check plants just failed to reach significance at the 5 per cent level.

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SEED DISINFECTION

II. EFFECT OF VARIOUS CHEMICALS ON THE EMERGENCE OF LETTUCE AND PEA SEEDLINGS.

By H. Jacks, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 13 October 1950*)

Summary

Lettuce and pea seeds were treated with commercial seed dressings alone and in combination with insecticides, a growth hormone, a nemacide, vitamin B and a copper compound.

Dusting with Spergon increased emergence of lettuce and pea seedlings while treatment with Agrosan GN was only effective for peas. Addition of DDT to Spergon and BHC to Agrosan GN did not materially affect the influence of these substances on the emergence of seedlings.

Fixtan, a liquid seed dressing, was not as effective as the dusts Spergon and Agrosan GN. In some cases addition of a growth hormone, vitamin B and arseno venadic acid, to Fixtan brought about an increase in emergence as compared with results given by Fixtan alone. Results, however, were not consistent. Addition of copper did not affect emergence figures in glasshouse tests of either lettuce or pea seedlings as compared with those given by Fixtan. In the field, however, this mixture reduced emergence of lettuce seedlings.

Introduction

The object of trials described in this paper was to determine whether various substances such as insecticides, a growth hormone and other materials could be added to commercial seed dressings without detriment to the emergence of lettuce and pea seedlings.

Experimental Methods

Lettuce seed of the variety Imperial, and pea seed of the variety Laxton Superb were used. Seed dressings are listed in Table I.

Dusts were applied to lettuce seed at the rate of 2.0 per cent and liquids at 0.5 per cent of seed weight. All materials were applied to pea seed at the rate of 0.25 per cent of seed weight.

In a previous paper the author (Jacks, 1951) has described methods of application of materials to seeds, the procedure followed in the trials and the methods used in recording the results. In these trials the height of tops from ground-level upwards and the fresh weight of healthy seedlings were also recorded.

Percentages emergence in sets of data containing values below 20 per cent or above 80 per cent were transformed to corresponding angular values before analysis (Fisher and Yates, 1948). Data containing values of 0.0 per cent were transformed to $\sqrt{\times} + \frac{1}{2}$ for analysis. For purposes of simplifying Tables II and III the transformed values are given in full. Means only, of actual emergence figures from all tests are also given in the tables.

Results

Glasshouse tests

These tests were carried out at a glasshouse temperature of 18 ± 3°C. Results are given in Tables II and III.

The general result shown is that few of the substances added affected the efficiency of the original compounds. Spergon gave the best results.

TABLE I. LIST OF MATERIALS USED

No.	Material	Active ingredients	Purpose for which used
	Dusts		
1	Spergon	96.0% tetrachloro-para-benzoquinone	Seed dressing for protection against soil-borne fungi.
1a	" DDT	96.0% tetrachloro-para-benzoquinone + 1.2% dichloro-diphenyl-trichloro-ethane	As in (1) + insecticide
2	Agrosan GN	1.0% mercury	As in (1)
2a	PP 1997	1.0% mercury + 20.0% benzene hexachloride	As in (1) + insecticide
	Liquids		
3	Fixtan	0.125% phenyl mercury	As in (1)
3a	" Horm.	0.125% phenyl mercury + 200 p.p.m. alpha naphthalene acetic acid	As in (1) + growth hormone.
3b	" VIT	0.125% phenyl mercury + 3 p.p.m. vitamin B.	As in (1) + vitamin to improve germination at low temperatures.
3c	" CV	0.125% phenyl mercury + 3.0% arseno venadic acid	As in (1) + nematode repellant.
3d	" VAP	0.125% phenyl mercury + 10.0% copper	As in (1) + copper for improved protection against pre-emergence damping-off.

TABLE II. GLASSHOUSE TEST. MEAN PERCENTAGE EMERGENCE (TRANSFORMED VALUES) OF LETTUCE SEEDLINGS IN SOIL MAINTAINED AT THREE LEVELS OF WATER HOLDING CAPACITY (w.h.c.)

No.	Treatment	Healthy seedlings					Diseased seedlings				
		Percentage w.h.c. of soil			Mean	Mean % emerg.	Percentage w.h.c. of soil			Mean	Mean % emerg.
		25	45	65			25	45	65		
1	Spergon	66.0	67.2	45.6	59.6	73.2	0.7	0.7	2.3	1.2	2.3
1a	" DDT	73.7	63.4	49.5	62.2	79.9	0.7	0.7	1.7	1.0	0.6
2	Agrosan GN	59.2	53.7	41.4	51.4	60.7	2.3	1.0	2.4	1.9	2.7
2a	PP 1997	62.0	56.8	43.9	54.2	65.3	1.6	1.3	2.4	1.8	2.9
3	Fixtan	58.6	61.0	40.7	53.4	64.1	1.5	2.6	2.0	2.0	3.6
3a	" Horm.	45.8	57.3	37.4	46.8	52.7	2.5	4.0	2.3	2.9	8.8
3b	" CV	68.9	58.1	42.1	56.4	68.0	0.7	2.3	3.2	2.1	5.0
3c	" VIT	63.4	60.6	30.0	51.3	60.2	2.5	2.4	2.5	2.5	5.6
3d	" VAP	65.2	55.6	43.9	54.9	66.1	1.9	3.9	3.3	2.7	9.5
4	Control	56.7	50.2	34.4	47.1	53.5	3.3	4.0	3.7	3.7	13.1
Difference required for significance at 5% level		Treatment X moisture level 15.6			8.9	-	Treatment X moisture level 2.1			1.2	-

TABLE III. GLASSHOUSE TEST. MEAN PERCENTAGE EMERGENCE (TRANSFORMED VALUES) OF PEA SEEDLINGS IN SOIL MAINTAINED AT THREE LEVELS OF WATER HOLDING CAPACITY (w.h.c.)

No.	Treatment	Healthy seedlings					Diseased seedlings				
		Percentage w.h.c. of soil			Mean	Mean % emerg.	Percentage w.h.c. of soil			Mean	Mean % emerg.
		25	45	65			25	45	65		
1	Spergon	62.0	72.5	51.3	61.9	77.0	8.1	5.7	14.6	9.5	3.1
1a	" DDT	56.7	64.3	46.5	55.8	66.8	13.5	12.7	13.2	13.2	5.7
2	Agrosan GN	52.2	53.9	33.7	46.6	52.9	24.6	21.3	27.5	24.5	17.3
2a	PP 1997	51.7	64.8	34.7	50.4	58.8	30.7	20.0	22.2	24.3	18.2
3	Fixtan	35.3	47.2	23.6	35.4	34.3	41.0	29.4	19.5	30.0	26.1
3a	" Horm.	45.0	59.3	17.9	40.7	44.3	38.5	29.3	12.2	26.7	25.1
3b	" CV	40.5	43.6	36.7	40.2	41.8	34.1	37.3	19.9	30.4	27.1
3c	" VIT	36.0	55.4	27.0	39.5	41.3	30.1	34.6	17.0	27.2	22.7
3d	" VAP	39.0	47.0	22.5	36.2	36.1	36.6	36.7	18.0	30.4	27.2
4	Control	38.9	44.8	10.9	31.5	31.0	32.9	31.0	13.4	25.8	20.6
Difference required for significance at 5% level		Treatment X moisture level 11.1			6.4	-	Treatment X moisture level 1.3			0.7	-

TABLE IV. FIELD TEST. MEAN PERCENTAGE EMERGENCE OF LETTUCE AND PEA SEEDLINGS (ACTUAL VALUES) FOLLOWING VARIOUS SEED TREATMENTS.

No.	Treatment	Lettuce seedlings		Pea seedlings	
		Healthy	Diseased	Healthy	Diseased
1	Spergon	67.0	3.8	82.0	5.0
1a	" DDT	68.7	7.0	81.3	5.7
2	Agrosan GN	41.8	6.3	64.3	6.3
2a	PP 1997	30.8	7.0	70.7	6.3
3	Fixtan	44.5	8.7	52.7	6.7
3a	" Horm.	50.3	9.7	53.3	7.0
3b	" CV	51.0	9.0	57.3	7.3
3c	" VIT	44.0	7.7	49.3	6.3
3d	" VAP	31.7	7.3	60.0	5.7
4	Control	28.6	10.3	61.3	11.7
Difference required for significance at 5% level		12.2	2.9	8.0	2.5

Addition of arseno venadic acid improved the emergence of lettuce as compared with results given by Fixtan and other mixtures but figures were not higher than those given by Spergon. Separate records of healthy and diseased seedlings gave a better criterion of the value of seed dressings than records of total emergence; this applied especially in the case of peas.

Field tests

These tests were carried out at temperatures of 4.4 ± 5.0°c. and at soil moistures of 43.9 ± 4.0 per cent water holding capacity (w.h.c.). Results are given in Table IV.

On the whole, judging from the data obtained with both species of plants, the addition of various substances did not affect emergence as compared with Spergon, Agrosan GN and Fixtan. An exception occurred in the case of Fixtan VAP, where the addition of arseno venadic acid depressed emergence of lettuce as compared with results given by Fixtan alone.

Records of plant weight

Fresh weight of plants was recorded both in glasshouse and field tests at approximately 15 days after emergence of lettuce and 30 days after emergence of pea seedlings. Results are given in Table V.

TABLE V. EFFECT OF SEED TREATMENTS ON FRESH WEIGHT OF LETTUCE AND PEA SEEDLINGS IN GLASSHOUSE AND FIELD TESTS

No.	Treatment	Weight of plants in grams			
		Glasshouse tests		Field tests	
		Lettuce	Pea	Lettuce	Pea
1	Spergon	0.037	1.1	0.056	2.7
1a	" DDT	0.036	1.2	0.054	2.5
2	Agrosan GN	0.037	1.1	0.050	2.3
2a	PP 1997	0.039	1.2	0.040	2.0
3	Fixtan	0.031	1.0	0.036	1.8
3a	" Horm.	0.037	1.2	0.054	2.4
3b	" CV	0.031	1.2	0.052	2.4
3c	" VIT	0.034	1.3	0.050	2.4
3d	" VAP	0.034	1.1	0.049	2.3
4	Control	0.038	0.9	0.052	1.7
Difference required for significance at 5% level		0.004	0.15	0.009	0.5

None of the treatments increased the weight of lettuce plants whereas all treatments except Fixtan and PP 1997 (which gave variable results) improved the weight of peas. Adding various substances improved the effect of Fixtan on fresh weight of peas and reduced injury to lettuces.

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GROUND SERPENTINE, AN EFFECTIVE SOURCE OF MAGNESIUM FOR GLASSHOUSE TOMATOES

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Summary

Ground serpentine, applied at the rate of 15 tons per acre, prevented the development of magnesium deficiency in glasshouse tomatoes growing in a magnesium deficient soil, and gave increased yields of high quality fruit.

INTRODUCTION

It is generally conceded that the soil correctives advocated up to the present day for the control of magnesium deficiency in glasshouse tomatoes have not been as effective as magnesium sprays[1, 2, 3, 4, 5, 6, 7].

Though excellent results have been obtained with sprays containing 2 per cent Epsom salts, this method of application is not favoured by commercial growers because of the time and labour involved. Further, though it has been shown by Nicholas[4] that the magnesium sulphate may be incorporated with a spray to control leaf mould, it has been reported[7, 8] that cases of injury have occurred when the magnesium sulphate has been applied to plants with or immediately after an oil emulsion spray.

A reliable soil corrective is therefore needed.

The magnesium fertilizers used to date may be grouped as: (a) neutral soluble salts, in particular magnesium sulphate and the magnesium phosphate component of serpentine superphosphate; and (b) relatively insoluble alkaline materials, dolomite and magnesite.

Though Owen[7] is reported as stating that in his experience magnesium deficiency is not corrected by soil dressings, some measure of control has been accomplished by Long Ashton workers, by means of heavy soil dressings of magnesium sulphate[1, 2, 3, 4]. As many glasshouse soils already have very high concentrations of soluble salts, however, the benefit from the addition of the magnesium ion to correct the magnesium deficiency is likely to be offset by the harmful effects of the further heavy additions of sulphate ion[9, 10]. It may be possible, as shown by Owen[11], to reduce this accumulation of water-soluble anions by flooding with large quantities of water, but this procedure is inconvenient, and may have undesirable effects on soil structure, and therefore on aeration, microorganism activity and incidence of disease.

Serpentine superphosphate applied as a substitute for normal superphosphate supplies insufficient magnesium in one or two seasons to overcome a deficiency[6], though its long term effect may be important.

Because of their marked effect on the pH of the soil, dolomite or magnesite cannot safely be applied at heavy rates, particularly on typical glasshouse soils already brought to a high percentage saturation with ground limestone or lime.

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* Died November 1951.

Clearly, in glass houses where the same soil is used for an extended period without renewal, a slowly active and neutral, but potentially large source of available magnesium is required. In theory, a magnesium silicate such as serpentine should comply with these requirements.

The present investigation was carried out to test the efficacy of a heavy dressing of ground serpentine as a supplier of available magnesium to glasshouse tomatoes on a magnesium deficient soil.

The results in the first season were sufficiently outstanding to warrant this interim report.

Experimental Procedure

Field Experiments

Experiment 1: Half of one house (House 5) was treated with 10 cwt serpentine (35 per cent MgO), ground to pass No. 18 British Standard wire-mesh sieve, as specified in the regulations governing the fineness of grinding of serpentine for the manufacture of serpentine superphosphate. This application (nearly 15 tons per acre) was rotary hoed to a depth of 6-7 in. along with the base fertilizer, 20 tons per acre stable manure (mainly bedding straw) were worked into the soil two months before planting. Base and side dressings were similar to those described for the main crop tomatoes in the 1949 experiments[6]. The tomatoes (Potentate variety) were planted out on 2 July, 1950.

Experiment 2: For comparison with spraying, blocks in a similarly treated house (House 2) were given five spray treatments with 2 per cent Epsom salts with a spreader, commencing 17 days after planting out. The treatments used 400 lb Epsom salts per acre.

Plant Analyses

Plant samples (mid-stem leaves) were taken for analysis from both experiments at approximately the following growth stages: (a) First truss flowering; (b) Fifth truss flowering; (c) Fifth truss set; (d) Major fruit swelling; and (e) Major fruit ripening.

Results

Field Experiments

Experiment 1: Slight magnesium deficiency symptoms appeared on the lower leaves of a few of the control plants in late September. By 18 October, i.e. at the commencement of the major fruit swelling period, about one-quarter of the plants had severe symptoms on the lower leaves. By 31 October nearly 60 per cent of the control plants showed severe symptoms, and no plants were entirely free from chlorotic leaves.

Over the whole growing season no sign of magnesium deficiency was noted on any plants in the serpentine-treated block.

Several estimates of relative crop yields indicated an increase of about 1½ lb per plant from the serpentine treatment. The fruit was also of superior quality.

Experiment 2: At 6 November, about 90 per cent of the control plants were showing deficiency symptoms. By 27 November, all control plants were affected.

The spray treatments gave similar results to the serpentine treatment, indicating that the yield response to the serpentine was due to the correction of magnesium deficiency, and not to some other factor.

Plant Analyses

Tissue tests: The magnesium (Mg) levels in the main petioles and in the laminæ are shown in Table I. The Carolus extraction technique[12] was used, and the results are expressed as parts per million of fresh tissue (see previous paper[6]). The average sample included representative material from both healthy and affected plants. The "chlorotic" sample was selected from severely affected plants only. The mid-stem leaves taken for analysis on 18 October from the controls to the serpentine experiment showed only slight evidence of chlorosis. Though about one-quarter of the plants had severe symptoms on the *lower* leaves most of the *midstem* leaves were still free from symptoms. By 6 November, even the midstem samples were severely affected.

TABLE I. MAGNESIUM IN 2 PER CENT ACETIC ACID EXTRACTS OF PETIOLES AND LAMINAE OF MID-STEM LEAVES (expressed in parts per million)

Treatment	Dates of Analyses									
	7/8/50		11/9/50		4/10/50		18/10/50		6/11/50	
	Pet.	Leaf	Pet.	Leaf	Pet.	Leaf	Pet.	Leaf	Pet.	Leaf
House 5										
Control (a) average	190	200	230	390	250	70	390	190	440	130
(b) chlorotic							440	120	460	13
Serpentine	330	400	430	500	410	540	560	480	1050	430
	9/8/50		21/9/50		16/10/50		6/11/50		27/11/50	
House 2										
Control	210	130	410	810	410	550	580	220	520	115
Mg spray	280	230	380	720	440	990	500	700	990	900

TABLE II. TOTAL MAGNESIUM IN WHOLE LEAVES (per cent dry matter)

Treatment	Dates of Analyses				
	7/8/50	11/9/50	4/10/50	18/10/50	6/11/50
Control, average sample	0.27	0.26	0.23	0.24	0.39
severely chlorotic				0.23	0.29
Serpentine	0.59	0.50	0.43	0.62	0.58

TABLE III. SOIL ANALYSES

Sample	Depth (in.)	pH	Base Exchange Capacity (m.e.%)	Exchangeable bases			
				Ca (m.e.%)	Mg (m.e.%)	K (m.e.%)	Na (m.e.%)
Control	0 - 6	5.7	29.6	23.3	0.98	2.26	0.44
	6 -12	6.2	25.9	17.5	0.77	2.09	0.29
Serpentine	0 - 6	5.8	29.4	19.7	2.18	2.91	0.53
	6 -12	6.0	28.1	19.6	1.12	2.17	0.27

Ash Analyses

The total magnesium (Mg) levels for whole mid-stem leaves from Experiment 1 are shown in Table II.

Soil Analyses

The results of analysis of soils from Experiment 1 taken on 7 November during the major fruit ripening period are shown in Table III. The figures reported are pH, base exchange capacity and milli-equivalents per cent of exchangeable bases. The exchangeable bases include cations of any soluble salts present.

Note.—Both the control and serpentine blocks received approximately 3 tons per acre serpentine superphosphate (9 per cent MgO) in the 1949 season, hence the "medium" level (0.88 m.e. per cent) of exchangeable magnesium in the control. This level, however, has been insufficient to prevent the development of severe deficiency symptoms.

DISCUSSION

All the evidence from the magnesium sulphate spray and serpentine experiments indicates that the response to serpentine was in fact a magnesium response.

The rate of application used is quite economic for glasshouse tomatoes. The value of the increased yield in this first season's crop from the serpentine application was several times in excess of the total cost of the treatment.

The efficacy of the serpentine in this experiment conflicts with the evidence from the work of MacIntire *et al.*[13], who found that serpentine used on an acid soil at an economic rate of about 3½ tons per acre was not an effective source of nutrient magnesium for red clover. Their rate of application may, however, have been insufficient. On the other hand, it is likely that the growth of the clover, and therefore the absolute uptake of magnesium by the plants, may have been severely limited by toxicities associated with an unfavourable acid soil condition (pH 4.9 - 5.1).

In a previous paper,[6] it was shown that the critical magnesium level for the appearance of magnesium deficiency symptoms was approximately 200 p.p.m. of the fresh laminar material, as determined in 2 per cent acetic acid extracts of crushed tissues, or 0.4 per cent in the dry matter of whole leaves. These criteria have been confirmed from analysis of leaves from the control plants in the present experiments, and the superiority of laminæ over petioles for diagnostic purposes has again been indicated. The tissue test and ash analysis figures show clearly that the serpentine has supplied sufficient magnesium to maintain the internal concentration above this critical level, especially during the important period of greatest demand for fruit swelling and ripening.

The soil analyses show that the pH has not changed and the exchangeable magnesium has built up only to a small extent, from an average of 0.88 m.e. per cent to 1.65 m.e. per cent in the 0-12 in. depth. This represents an increase in the percentage of the exchange capacity from 3.2 to 5.7. In the 0 - 6-in. layer the increase was from 3.3 to 7.4 per cent. Prince, Zimmerman and Bear[14] set approximately 6 per cent as the requirement. On this basis, using the criterion of exchangeable

magnesium, the 15 tons per acre rate of application appears to be barely sufficient. It is possible, however, that smaller dressings might still be effective if tomatoes are able to obtain their magnesium needs from the added serpentine by a direct contact exchange mechanism, such as postulated by Jenny and Overstreet[15].

In the present experiment the material applied was the normal works product used in the manufacture of serpentine superphosphate. With finer grinding, smaller applications should be effective.

Future work is planned to determine (1) whether this massive application of 15 tons per acre can be reduced, and (2) whether the beneficial effect of the heavy dressing will persist for many years.

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